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# The Implementation and Evaluation of Virtual Reality in Geographical Education

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# The Implementation and Evaluation of Virtual Reality in Geographical Education

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# Abstract

Working with the Education University of Hong Kong, this project's goal was to develop and test a pilot lesson to investigate virtual reality as a learning tool in secondary geography education in Hong Kong. Two versions of the lesson, one supplemented with 360-degree pictures and one as a traditional lesson, were presented to secondary school students. Pre-test and post-test scores, surveys, as well as feedback from teachers-in-training were used to evaluate the effectiveness and feasibility of virtual reality in teaching a module on coastal landforms. Our results on the effectiveness of VR were inconclusive, but they showed that VR is feasible. A lesson on urban problems was also developed. Recommendations for additional pilot studies and content development were provided.

# Acknowledgements

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# Executive Summary

Virtual reality (VR) has been greatly improved upon in recent years. Many of these improvements have been made directly to the technology, but VR has also become much more widely accessible. One of the new applications for VR is its use in education. Geography has demonstrated a particular affinity to VR technology. With the learning objectives of geographical and environmental education having a large emotional part, the realism of a VR field trip has a great potential in replacing physical field trips when the field location is inaccessible or inconvenient.

The Hong Kong Curriculum Development Council and The Hong Kong Examinations and Assessment Authority have recently added a field trip requirement to the geography curriculum for secondary school students, to be effective in 2019. Teachers are concerned that they will not have enough time to schedule these field trips. Our sponsors at the Education University of Hong Kong are looking into the feasibility of replacing some of these field trips with virtual substitutes.

The goal of this project was to determine the desirability and feasibility of using VR in geographical education by designing and testing a pilot program for secondary school students in Hong Kong. This project was a preliminary stage in implementing VR in geographical education. A pilot lesson was designed based on content from current secondary 4-6 level geography textbooks. One of the content areas our sponsors suggested was the coastal environment. We visited two remote Hong Kong locations, Tung Ping Chau and High Island Reservoir, to take 360 degree pictures to supplement the lecture. A second lesson was also designed to cover topics on urban development, urban problems and urban renewal. We visited Mong Kok and City One to take 2D and 3D pictures to supplement the lesson plan.

The lesson plans were modeled after different lesson examples given to us by our sponsors. From those lessons, we created our lessons with a similar structure in terms of planning, adding in time durations with teacher activities and student activities. Additionally, we created worksheets to act as guiding notes for the students during the lessons. For the virtual reality lesson, we used the Google Cardboard to display the pictures.

Our sponsor invited us to survey some of his first year university geography students about the use of VR in education. Since these students were training to become teachers, their opinion was of great value to us, as they were a medium between the opinions of both teachers

and students. Additionally, they represented the next generation of teachers, who may be the first generation to use this technology regularly in their classrooms. In general, these teacher-students responded positively to the use of this technology, but some feared that it would not be a sufficient replacement for a traditional field trip. Another concern that these students demonstrated was that the VR lessons would take more time to prepare compared to a traditional lesson. Some teacher-in-training students also felt the need to have improvement in the technology itself before it could be implemented in schools, as these students felt dizzy after using the headset for an extended period of time.

Twenty secondary school students participated in the pilot VR lesson. We recorded observations as the lesson was presented. We observed that the students were able to learn how to operate the technology very quickly. After only a few iterations of viewing pictures, the students were able to set up the headsets and mobile phones without help from the teachers. We also observed that the technology could easily become a distraction from the lesson. Many students continued to use the VR headset after they were asked to put it down and pay attention to the lecture.

The pre/post tests were scored out of a total possible score of five points. The scores of the VR lesson showed an average improvement of 1.47 (SD 1.12) points, a statistically significant difference ($p < 0.05$). All but four students had an improvement of at least one point. We also compared the pilot lesson with a control group. Due to many differences in the two groups of students, we could not draw any conclusions from the comparison.

Our findings suggest that *VR is **feasible** for use in geography education*. There are some nuances that have to be improved upon. We recommend that our sponsors continue this research, and further analyze the *effectiveness* of the technology. A larger student sample and a wider variety of lessons would provide a larger pool of data to compare with traditional teaching styles. Also, we suggest that our sponsors follow the development of this technology, and possibly look into testing more sophisticated hardware that might make fewer students feel dizzy.

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# 1.0 Introduction

Technology has proven to be highly effective in education. From blackboards to smartboards and the use of the internet, technology has served as an extremely helpful tool in learning. Computers have allowed for access to a limitless reserve of resources. In environmental education, teachers and students can examine and research distant locations that may be ordinarily inaccessible, through the use of satellite imagery, remote sensing, underwater cameras and the like.

Since its inception, virtual reality (VR) has been a highly anticipated teaching tool. Recently, virtual reality has become much more economically and technically accessible for a classroom environment. The ability to create an immersive space offers enormous potential to supplement or substitute for field trips that are often an essential component of learning in environmental science and education.

Many studies have shown that the use of field trips is largely beneficial to students learning environmental education. However, field trips are currently underused by teaching staff. Field trips allow for an understanding that is far more in depth than a lecture could provide. A deeper understanding can be attained if there is a more personal, emotional connection to the topic. A field trip puts a student in an environment where they will invariably connect with their surroundings, just by being there. Virtual reality has already been adapted for several different uses in education. For example, virtual reality has been applied to certain cases of anatomy and marketing and has been shown to increase retention of information.

The goal of this project was to implement a virtual field trip experience in a secondary school classroom and then evaluate its effectiveness and feasibility. We gathered information from the Hong Kong secondary level geography curriculum to guide the development of a virtual reality pilot package. We used this information to aid us in the design process for the lesson. This package was implemented in an English language secondary school classroom in Hong Kong, as part of a full lesson, to assess the impact of virtual reality on retention of environmental education concepts. A pretest and a posttest were given to quantify retention of information for both the VR lesson and a control group. Additionally, surveys were used to collect opinions of first year university teacher-students on the pilot package’s feasibility. By implementing virtual reality in this pilot package, we were able to gather information regarding students' opinions, as well as information regarding knowledge attained.

# 2.0 Literature Review

In this review of the literature, we look into technology that is currently used in education. Next, we examine how virtual reality is used in education. Then, we address past and current learning objectives in environmental education, and how they are achieved. And finally, we explain how we think virtual reality can best be implemented in environmental education.

## 2.1 Technology in Education

Technology has always been perceived to be beneficial to learning. Integrating technology into education “can help promote learning and understandings about local and global environmental issues that are vast, complex, and difficult to personally engage with, and cannot be easily visualized or understood” (Peffer, Bodzin, & Smith, 2013). Students are able to separate information into smaller, more focused sections of material and focus on specific areas of information at a time. By teaching with case-specific information, students are “encouraged to process complex information by coordinating multiple cognitive skills in a manner replicating experts’ thinking processes” (Peffer et al., 2013).

Iding, Crosby, and Speitel (2002) surveyed teachers, in which 95% of participants either rated the use of computers and technology as absolutely essential, very important, or important to learning. Some of the teachers surveyed believed that “books may become outdated” (Iding et al., 2002, 159), meaning that the content in these books will be stored by other means. Students benefit largely from the use of technology, as technology allows teachers to circumvent gaps in student knowledge, or necessary skills that may inhibit student learning capabilities. Online video resources have become widely available and "enable[s] students to understand complicated sections in an easier and concrete manner" (Chiu, 2016). Additionally, technology even allows students and researchers alike to reach areas that are physically inaccessible to them (Peffer et al., 2013). Images of unreachable areas provide visualization that would not be present otherwise. Technology proves to be a valuable resource that students and teachers can benefit from. Recently, virtual reality has become a new technology adapted into education.

## 2.2 Virtual Reality in Education

### 2.2.1 What is Virtual Reality?

"Virtual reality means creating immersive, computer-generated environments that are so convincing users will react the same way they would in real life" (Emspak, 2016). By creating visual and auditory stimulations, users are placed in a virtual environment that relates the real world to an imaginary one. Real-life movements are tracked and replicated within the virtual reality program to produce a convincing, realistic perception of a generated world.

There are several different virtual reality products currently in the market. The most basic of these is the Google Cardboard (Figure 1), a cardboard headset mount for a smartphone. The Google Cardboard is an inexpensive option for consumers ($15, plus the cost of a smartphone), both easy to set up and to use, to try virtual reality without having to invest in expensive hardware. The disadvantage to Google Cardboard is that the specifications are limited to the user's smartphone (Get Cardboard, 2016). In contrast, the Oculus Rift (Figure 2) is computer based peripheral. It has access to a computer's much larger CPU to process simulation data. This increase in power, however, requires the user to be tethered to a computer (Oculus Rift, 2016). The HTC Vive (Figure 3) is a similar headset that also supports room scale VR. If small sensor towers are mounted in the corners of the room, the Vive is able to detect the location of the user in the room and add that information into the simulation. This feature allows the user to walk around a virtual space instead of merely looking around it. The biggest disadvantage to the Vive is that it requires the entire room to be dedicated to virtual reality and an extensive setup of both the sensor towers and the processing computer (VIVE™, 2016).

*Figure 1: Google Cardboard headset: US$15 (Get Cardboard, 2016)*

*Figure 2: Oculus Rift headset: US$599 (Oculus Rift, 2016)*

*Figure 3: HTC Vive headset (center), Tower Sensors (upper left and right), Hand Controllers (lower left and right): US$799 (VIVE™, 2016)*

### 2.2.2 Virtual Reality Educational Applications

Virtual reality is currently being used to further improve upon education. By developing a personalized world, users become immersed in an experience without the fear of real world consequences. For example, one study applied virtual reality to marketing. This study consisted of a virtual supermarket where a woman would approach a student, asking questions about how choices in the supermarket were made. The answers were then recorded and evaluated by a professional. Both a pretest and a posttest were given to the students and a control group of students who received a traditional lecture, and the immersive, virtual reality experience proved to be more effective in teaching marketing learning objectives than a traditionally taught lesson. The lesson was seen to be more personal than traditional teaching, and thus, students were able to interact with the material more and were more motivated to learn (Cheng & Wang, 2011).

In 2010, a study evaluated user experience of virtual reality in anatomy education. This study hypothesized that increased immersion would result in increased motivation that would, in turn, provide a stronger structure for problem-solving capabilities. After use of the virtual reality technology, the students tested in this study were surveyed, showing that the majority of the students found virtual reality to be beneficial to their learning. They indicated that there was a strong feeling of enhanced education, as well as a sense of realism (Huang *et al.*, 2010).

Pasqualotti & Freitas (2002) studied the effects of virtual reality in education, but in relation to 3D modeling as a teaching tool for mathematics. This study used MAT3D, a virtual reality modeling language environment that allowed students to generate shapes and view them three-dimensionally. These models allowed students to freely explore different shapes and mathematical concepts in a more interactive way. This study concluded that students did not need prior knowledge of the subject in order to benefit from this technology. The interactive software proved to be able to teach students of all backgrounds. The results of this study showed that, from the use of 3D modelling, students were better able to grasp an understanding of geometric concepts (Pasqualotti & Freitas, 2002).

## 2.3 Environmental Education

### 2.3.1 Bloom's Taxonomy in Environmental Education

Bloom's Taxonomy (Figure 4) is a structure designed by Benjamin S. Bloom to describe the different levels of understanding attainable by learners. As a learner moves towards a deeper understanding of a certain topic, they show similar patterns of learning throughout their progress. It begins with the ability to recall factual statements about a given topic, and then moves towards interpreting and classifying, next comes application to a task, finally to creation, in which the learner has a concrete, novel, comprehensive understanding of the said topic.

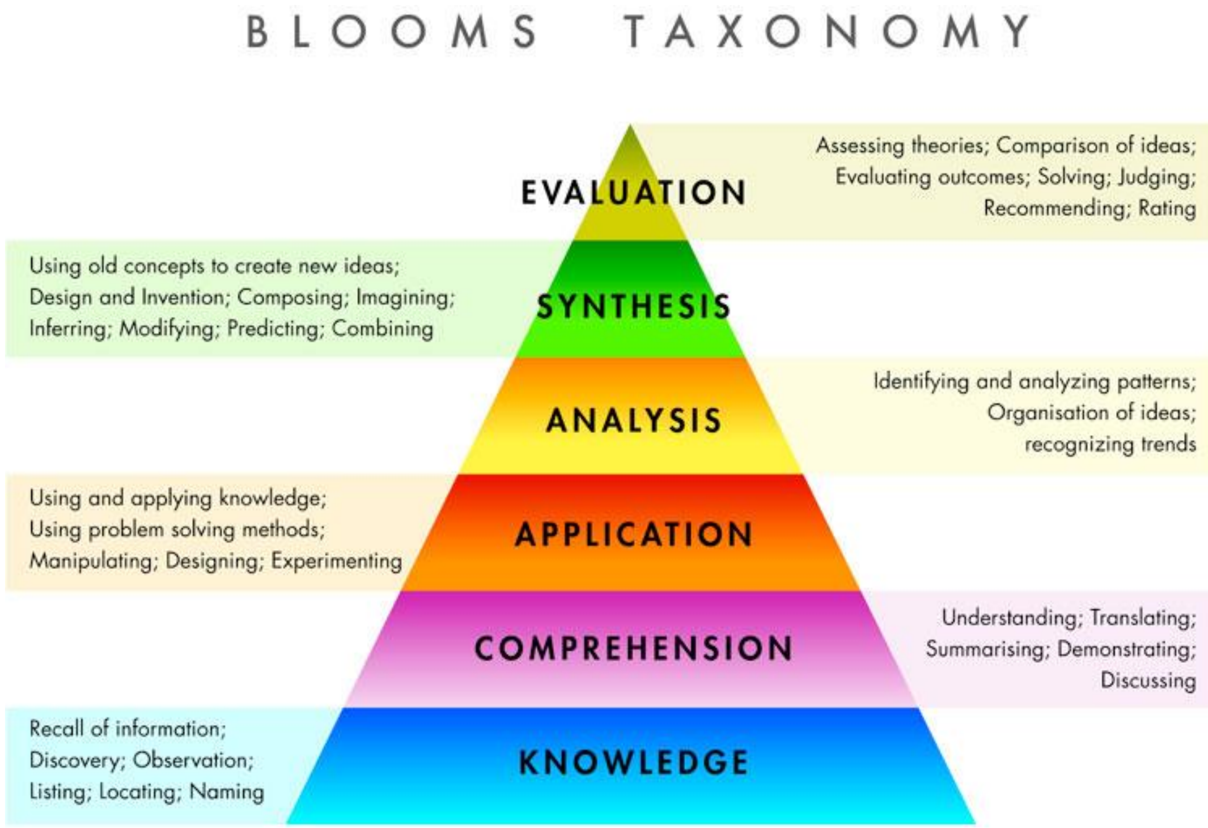


*Figure 4: Bloom's Taxonomy Diagram (Alford et al., 2006, as cited by Julia Cornwell, 2011)*

Learning can be differentiated into different domains: cognitive, affective, and psychomotor. As described by Kearney (1985), "The affective domain of learning refers to students' attitudes, beliefs, and values toward the subject matter and learning experience" (p. 63). Kearney (1985), Bloom (1956) and Krathwohl et al. (1964) found that an even deeper cognitive domain level of understanding would be achieved if the affective domain emotional attachment was present (Figure 5).

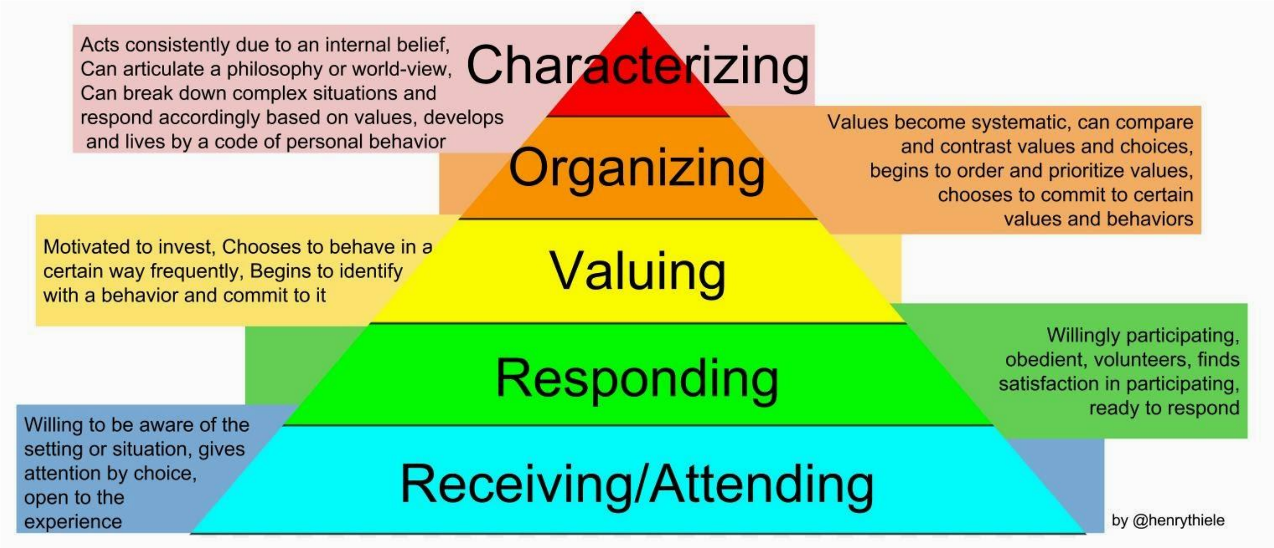


*Figure 5: Taxonomy of the Affective Domain (Henry Theile, 2015)*

In applying these ideas to environmental education, students may struggle to surpass the knowledge level of simply recalling facts through classroom learning. If the learner is not able to make emotional connections from the topic to the real world, the level of knowledge attained by the learner is not as strong (Kearney, 1985; Krathwohl, 2002). Many times, in order to address this problem, teachers will use a field trip to allow their students to make a more personal connection to the topic being covered (Berliner, 1985).

### 2.3.2 Learning Objectives in Environmental Education

When teaching environmental education, many topics can be addressed. Ultimately, these topics share many of the same learning objectives. Stapp (1969) defines four learning objectives of an environmental lesson. First, the learner has to understand that they personally, and people collectively, are inseparably connected to the environment as a whole. Second, the learner must be able to obtain a broad knowledge of the biophysical environment around them, both natural and man-made, and how it is integrated in society, and vice versa. Third, the learner must gain knowledge of the biophysical problems surrounding the environment, as well as how these problems can be solved (i.e. personal changes to a lifestyle, or government law). Fourth, the lesson leads the learner to an attitude of concern and motivation to help be a part of the solution to a given problem (Stapp, 1969). This fourth objective specifically relates to the affective domain of Bloom's Taxonomy. In order to achieve this learning objective, a learner must be able to form a more emotional connection with the subject being taught. For an environmental lesson to achieve these goals, factual evidence must be provided to allow for the understanding of the biophysical environment as a whole. Many teachers believe that on the topic of environmental education, classroom learning is not sufficient in gaining a deeper level of knowledge (Peffer, 2013; Berliner, 1985).

As described in the guidelines for environmental education in New South Wales, the environment makes up every facet of the real world. Humans are interactive parts to this whole, and the quality of the world is completely dependent on the state of the environment. This policy describes a necessary preparation of its learners to maintain and restore the earth's environment. In addition to knowledge based learnings, the policy states that the curriculum should develop "positive and balanced attitudes" towards the environment and "respecting and valuing the achievements of the past". The policy also defines specific learning objectives. These include, but are not limited to: understanding the nature and function of ecosystems, understanding people's role in the environment, and the ability to apply technical expertise to an environmental context. Along with these knowledge-based skills, the policy states that students should learn to "[adopt] behaviours and practices that protect the environment", which reflects learning at the second or third level of the affective domain. This policy applies to students in both primary and secondary schools in New South Wales (Environmental Education Policy for Schools).

### 2.3.3 Field Trips and Their Role in Achieving Learning Objectives

Field trips are commonly used to achieve learning objectives in environmental education. Lisowski and Disinger (1991) conducted a study to evaluate the effect of field-based instruction for student understanding of ecological concepts. The results indicated that all participating groups showed significant increases in posttest scores. Four weeks after the posttest, a retention test was given to the participants, and it was noted that there was no significant loss in retention after the time gap. This study served to show the positive impacts of field-based learning for environmental education and that conceptual understanding is positively related to instructional emphasis.

According to Tuthill & Klemm (2002), "Field trips help bridge formal and informal learning, and prepare students for lifelong learning. Research has long demonstrated that using a variety of instructional strategies optimizes the effectiveness of teaching and learning. Field trips are one way of adding variety to instruction, thus optimizing teaching effectiveness while motivating student learning" (pg. 453). Field trips can provide an immersive experience that has been shown to increase retention among students. However, despite the clear advantages to field trips, relatively few teachers employ this method of teaching (Berliner, 1985; Krepel & DuVall, 1981; Orion, 1993). Krepel & DuVall (1981) stated that, from a pool of surveyed teachers, approximately 10 percent reported the use of field trips over the course of a school year. There were many reasons given in response as to why they did not conduct field trips, but the most notable were lack of funding, liability issues, and lack of openings in their schedules.

Many teachers chose not to teach certain topics in environmental education at all because they felt as though they were not able to bring their students to a location that would demonstrate such a topic. In other words, these teachers avoid the topic altogether because a field trip would be impossible. These reservations could be due to geographic limitation of the school, lack of funding for the field trips, or inherent dangers of the environment in question (Kim & Fortner, 2006).

### 2.3.4 Technology Currently Used in Environmental Education

Many educators, across all backgrounds, use technology to further achievement of environmental education learning objectives. Even though there are some environmental educators who feel technology detracts from these learning objectives, more educators feel that learning technologies provide the tools needed to teach when a natural environment is unavailable. For example, nearly all of the educators in a study done by Peffer et al. (2013) used some form of productivity technology (i.e. Microsoft Word, or spreadsheets). Although less often, a large population of educators who took part in this study also used presentation technology (i.e. slideshows, DVDs, projectors, etc.). Comparatively, only very few educators are using more advanced and modern technology in their teaching. Some examples of these are virtual field trips, computer simulations, or even educational video games. These results are tabulated in Table 1 and Table 2. Peffer et al. also surveyed the same educators to gather their opinions on whether or not technology aids in achieving the learning objectives of environmental education. On average, most educators who participated in this study agreed. The study also states that while the technology is widely accepted to enhance learning, many educators are unaware of its presence or capabilities, so many of the modern technologies go unused.

*Table 1: Most Popular Technologies Used in Environmental Education (Peffer et al. 2013)*

| *Type of technology* | % | n |
|---|---|---|
| Productivity | | |
| Word processing (i.e., MS Word for creating information sheets) | 95.3% | 387 |
| Spreadsheets (i.e., Excel to access and interpret data) | 77.1% | 313 |
| Publishing (i.e., MS Publisher, Adobe Page Maker for disseminating pubic brochures) | 65.0% | 264 |
| Database software (i.e., MS Access to compile or accumulate data or contacts) | 44.1% | 179 |
| Total productivity respondents | 96.1% | 390 |
| Presentation | | |
| Digital photography | 64.5% | 262 |
| VHS/DVD video (pre-made to highlight content) | 63.5% | 258 |
| Overhead projectors | 49.8% | 202 |
| Public education (Kiosk or interactive wayside) | 40.6% | 165 |
| Digital opaque image projector (Devices that project objects or pages to a large screen, i.e., ELMO) | 24.4% | 99 |
| Other presentation technology (i.e., PPT software, other projectors, SMARTboard, CD music or text, MP3, WebPages, podcasts) | 14.0% | 57 |
| Total productivity respondents | 94.8% | 385 |

*Table 2: Less Popular Technologies Used in Environmental Education (Peffer et al. 2013)*

| *Type of technology* | % | n |
| --- | --- | --- |
| Virtual field trips (i.e., Estuary-Net project through National Estuarine Research Reserve System) | 15.3% | 62 |
| Simulation, Modeling, or Gaming learning software | 14.8% | 60 |
| Guided chats (i.e., Internet discussion board or Wiki with directed topics) | 13.5% | 55 |
| Online journaling (i.e., BLOGs) | 10.3% | 42 |
| Clickers (i.e., Classroom response tools) | 9.6% | 39 |
| Other learning technologies (i.e., navigation equipment, mobile interactive technology vehicle, remotely operated vehicles, web quests, semantic networks | 2.0% | 8 |
| Total learning technologies respondents | 78.6% | 319 |

Virtual field trips (VFTs) are another technology currently being used in environmental education. VFTs have varying definitions, from a point-and-click web page, all the way to a nearly fully immersive video game like adventure. Traditionally, VFTs are not used in conjunction with virtual reality. VFTs are a good alternative to actual field trips, but they cannot be a lesson in and of itself. A good VFT must show certain characteristics, as described by Robinson (2009), in order to achieve environmental education learning outcomes (Table 3). With these characteristics included in a VFT, the VFT can “encourage and support the development of a discursive and collaborative environment in which the teacher and students take responsibility for the learning that takes place” (Robinson, 2009, 14).

*Table 3: Characteristics of a Good VFT (Robinson, 2009)*

| | |
|---|---|
| a. | They are goal-directed with curriculum links |
| b. | They are based on authentic contexts |
| c. | They encourage the sharing of responsibility |
| d. | They provide multiple modes of expressions and various modes of learning |
| e. | They use interactive multimedia technology |
| f. | They make significant use of both synchronous and asynchronous communication. |
| g. | They recreate a semblance of reality |
| h. | They provide additional support for teachers and students, e.g., lesson plans and implementation guidelines |
| i. | They should reflect the elements of good web design |
| j. | They should be based on sound pedagogy and educational theory |

Qiu & Hubble (2002) conducted a study on the effectiveness of VFTs without the use of virtual reality, in which they determined some advantages and disadvantages of VFTs (Table 4). Some of the advantages include presenting a location that is not easily accessible and showing pictures from different viewpoints; VFTs can also be less expensive than a real field trip. Tuthill & Klemm (2002) also said that the use of videos provides a fluid narrative of a topic, which creates a vividness not found in a static representation. The media is also temporally independent, meaning that it captures the environment exactly as it was at the time. Some of the disadvantages that were noted included not being able to demonstrate environments in three dimensions, not having a feeling of discovery, and students can easily become lost. Many of these disadvantages can be addressed with the use of virtual reality.

*Table 4: Advantages and Disadvantages to Virtual Field Trips (Qiu & Hubble, 2002)*

| Advantages | Disadvantages |
|---|---|
| Integrate diverse types of data in instantly available ways | Do not convey the true three-dimensional nature of objects |
| Present images from a variety of viewpoints and at many different scales | Do not convey the non-visual and aural feelings of touch, smell, etc. |
| Display non-visual data (geochemistry, etc.) | Less beneficial than really being in the field |
| Helpful for presenting trips to inaccessible areas | Lack the serendipitous nature of discovery |
| Provide an alternative of fieldwork, when time, expenses, and/or logistics are real issues | Having limited interaction with a computer |
| Enable presentation of extensive field trips and great variety of landform diversity | Not interacting with people in a flexible manner |
| Enhance and expand students' experience | Visiting a website can be difficult and depends on many factors, such as availability of computers, load on the network, number of connections, reliability of service provision, etc. |
| Enable flexibility of access (time and place) | Easy for students to get lost among lots of websites |
| Provides a repeatable experience which can be used to reinforce concepts in class | Many websites are ephemeral rather than permanent |
| Provides an easily experienced preview or review of real field trips | Often difficult to find a suitable one for teaching and learning |
| Hold abundant materials and information | The abundant websites are not quality controlled |
| Offer rich resources of learning and teaching | it is easy for students to wallow, or obsess over particular sites, which raises the problem of time management |
| Available for users of different levels and demands | |
| Interesting and attractive to students and an alternative experience for users | |

## 2.4 Virtual Reality for Use in Environmental Education

Virtual reality has been a highly anticipated technological addition to environmental education. "Since the beginning of the 1990s, as an alternative to actual fieldwork, the virtual reality has been regarded as a cheaper way of doing field trips. Virtual field trips basically emulate the actual field trips. They have a valuable role in supporting and enhancing real fieldwork and empowering students who are disadvantaged financially or physically” (Çaliskan, 2011). Virtual reality serves to replicate virtual field trips with a more immersive quality. Virtual field trips are a great alternative when the real environment is dangerous, difficult to get to, the learner could harm the environment or situations where it is difficult to physically observe (Fan et al., 2010). Taylor et al. (1997) identified a few barriers to the use of virtual reality, including lack of funds, fear that virtual reality experiences would replace or be substituted for real experiences, lack of technical training for educators, and lack of evidence of VR’s education effectiveness. However, these barriers have dissolved since the ’90s as advancements in computer hardware has led to virtual reality being financially accessible to the general public. In addition to the widespread accessibility, it has become easier to use and does not require significant technical training to operate. Virtual reality is unlikely to replace field trips as the general consensus has been that it should “be used alongside the actual field trip and not as an either/or situation” (Robinson, 2009). With the barriers to entry gone, virtual reality has the potential to thrive as an environmental education tool.

With recent improvements in virtual reality, it has been shown to be useful in other fields of study such as anatomy. We see this project as a chance to examine the effects of virtual reality in environmental education by eliminating barriers to adoption of virtual field trips. The immersion provided by virtual reality has the potential to have a greater effect in the affective domain. It may become an incredibly useful tool as an alternative or substitute to a field trip.

# 3.0 Methodology

The goal of our project was to determine the desirability and feasibility of using virtual reality (VR) in geographical education by designing and testing a pilot program for secondary school students in Hong Kong. In order to accomplish our project goal, we identified three objectives:

1. Identify suitable content for a VR pilot program for the Hong Kong secondary level geography curriculum.
2. Design and develop a virtual reality lesson for secondary school students based on the design criteria.
3. Test and evaluate the pilot VR lesson in a classroom setting with secondary school students.

In order to accomplish these objectives, we began by gathering more in-depth information about the secondary level geography curriculum in Hong Kong, as well as formulating a plan to design our pilot program. Much of this information was received from our sponsors at EdUHK.

## 3.1 Identifying Content

To begin this project, we examined recent revisions to the secondary 4-6 level geographical education curriculum in Hong Kong. Sources included geography textbooks, as well as the Hong Kong Secondary School curriculum for geography (Curriculum Development Council and The Hong Kong Examinations and Assessment Authority, 2015). In the secondary school education system, the education board now requires field work and field trips within the environmental and geographical education. For the lessons we designed, our sponsors chose two topics: coastal landforms and urban problems in a developing city. The textbooks gave us important information about urban problems in Hong Kong and how to mitigate their effects, as well as information regarding the formation of waves and their role in creating coastal landforms. The curriculum provided us with guiding questions that narrowed the scope for the content of the lesson. Education in Hong Kong is strictly structured to prepare students for the exit exams. The learning objectives from this document delineated topics that the students would be tested on in the future. The information gathered from the textbooks provided us with the content of the lessons.

## 3.2 Lesson Design and Development

Our lessons included a traditional, lecture style lesson, as well as a second lesson with a supplementary virtual reality module. The content of these lessons, provided by our sponsors, focused on Hong Kong's urban problems and coastal features that can be found in remote areas of Hong Kong. The lessons were designed to be approximately 45 minutes long, and the virtual reality module included additional 360° images. The lesson plans can be found in Appendix A: Lesson Plans.

### 3.2.1 Determine VR Field-trip Locations

For the image content of our lessons, our sponsors identified several specific locations to gather reconnaissance about each respective site. To cover the urban problems section of the curriculum, we scouted Sham Shui Po, Kwun Tong, and Mong Kok, in search of areas with specific categories of problems. These problems included older buildings that were in poor condition and in dire need of renovation, illegal living quarters, land use conflicts, and traffic congestion -- both for vehicles and pedestrians. We conducted a preliminary walkthrough of each of these areas while taking test pictures.

To cover the coastal topics, our sponsors suggested we visit two locations: High Island Reservoir and Tung Ping Chau. Table 5 indicates the specific features we looked for at each location. At Tung Ping Chau, we walked along the entire coastline, and at High Island Reservoir, our route circled the small body of water between the East Dam and Po Pin Chau. The specific features we looked for were determined by both our sponsors and the content of the textbooks. Although the textbooks covered information on other coastal formations and different concepts, we limited our pictures to what we could find around our two sites, in order for the lesson to be more representative of a field trip that could be done by the students as a formal trip.

*Table 5: List of coastal formations to photograph at Tung Ping Chau and High Island Reservoir*

| ***High Island Reservoir*** | ***Tung Ping Chau*** |
|---|---|
| Ria Coast | Dykes |
| Sea Caves | Pocket Beaches |
| Sea Stacks | Wave Cut Platform Seals |
| Cliffs | Sea Stacks |
| Coastal Defense | Sedimentary Rocks |
| Pocket Beaches | Wave Refraction |
| Volcanic Rocks | |
| Hexagonal Columns | |
| Folds | |

### 3.2.2 Collect Images

We used Panasonic Lumix G7 and Ricoh Theta S 360° cameras to capture all of the content for our lesson. Images were taken at both the High Island Reservoir site, as well as Tung Ping Chau Island. For locations that were either not accessible to us or needed to be seen from a higher view, we used a drone to fly the camera. We complied with Hong Kong's model aircraft law at all times. All hardware was generously provided to us by the Education University of Hong Kong.

During each trip, an Android app called Geo Tracker was used to record our GPS and time information and created a "track". This track could then be exported as a GPX file. We would then import the GPX file into a free program called GeoSetter along with the folder of photos. GeoSetter automatically geotags all the photos by matching the time the photo was taken to the time found in the track to estimate the position of the photograph. It would then add this information to the metadata of each image file.

We used Google cardboard to display our virtual reality content. Google Cardboard is an inexpensive phone accessory that turns a smartphone into a virtual reality headset. It is simple to use as it only has a single button on the side. It requires the user to download the Google Cardboard application onto a phone which then integrates into existing applications on the device in order to display content for virtual reality. By pressing a button in the application, the application switches into a virtual reality mode. For example, in the YouTube application, when watching a 360° video, if a user clicks the Google Cardboard button, it will change the display to a 3D view. We used the Google Cardboard Camera app to view the photos. To make a selection, a single button on the headset could be pressed to bring up a menu of all the pictures. A selection could be made by looking at the picture the student wanted to view, and then pressing the button again. The pictures were downloaded to the phones prior to the lesson, with different folders for each lesson. All of the post-processing of the images was done in either Adobe Photoshop CS6 or Gimp 2. We added text fields as titles and labels to help guide the student's viewing.

### 3.2.3 Lesson Design and Learning Objectives

The lessons were designed by following the structure of lessons based on the Hong Kong secondary school curriculum. This structure consisted of the duration, in minutes, of each section of the lesson, the purpose of each section, the teaching materials needed for each section, and the teaching methods used in each section. The lessons were designed to be 45 minutes long. Each lesson included a short, five-minute presentation about how to use the VR technology. The brief introduction to the technology explained how to properly navigate through the Google Cardboard application and where to find the images needed. Each lesson also included worksheets that acted as guided notes for the students to fill out during the lesson. The fill-in-the-blank style worksheets assisted students in remembering information presented to them in the PowerPoint slides. These worksheets can be found in Appendix B: Coastal Lesson Worksheet.

The first lesson covered the topic of Hong Kong coastal environment. The learning objective that we chose for the lesson plan was the cause and effect of waves in creating coastal landforms. The lesson was designed to attempt to reach the second and third level of Bloom's Taxonomy, as these levels are usually indicative of secondary school students. The lesson was created to teach the students about waves and the different kinds of waves that exist. Next, students learned how waves alter the coast to create landforms.

The second lesson was created on the topic of urban problems and urban renewal in Hong Kong. The three learning objectives that we chose for the lesson plan were to identify urban problems, to explain what factors cause these problems, and to develop an awareness of how people are affected by these problems. As with the coastal lesson plan, this lesson was designed to reach the second and third levels of Bloom's Taxonomy, levels appropriate for secondary school students. The lesson was designed to teach students about the urbanization cycle, problems associated with this growth process, and solutions, including urban renewal. Specifically, the urban problems of traffic congestion, mixed land use and substandard living conditions, along with associated solutions were included in the lesson. The lesson was also designed to allow students to explore how they are personally impacted and affected by these urbanization problems and their solutions.

A Pre/Post Test for each lesson was designed using questions found in a question bank provided to us by our sponsors. The questions were selected to provide a range of questions covering the subject material. These exams can be found in Appendix C: Coastal Pre/Post Test. For both classes, the test concluded with an opinion survey of the students' and teachers' feelings towards the lesson. Please see Appendix D: Survey for Students after Lessons and for these surveys.

### 3.2.4 Integrate VR and Other Images into Lesson Materials

Each lesson consisted of flat images taken at either Tung Ping Chau or High Island Reservoir, but the VR lesson was supplemented with additional 360° images (Appendix E: 360 Degree Photos). These pictures were compiled into a PowerPoint as two formal lessons (Appendix F: PowerPoint Slides). Both versions of the lessons (VR and traditional) used the same presentation, with slight differences to adapt to the 360° pictures. The virtual reality slides set included additional slides dispersed throughout the PowerPoint to direct the students to view the VR pictures. Students were able to use the images as visual examples of the material they were studying with VR content dispersed throughout. Each image emphasized the concepts we had identified in our review of the literature. In addition, we used the information that we gathered from our sponsor to guide our image selection.

### 3.2.5 Develop Teacher Manual

Since virtual reality is a relatively new technology, we assumed that most secondary students (and teachers) would not have extensive experience using it. We anticipated this might have caused some confusion during the lesson and impeded the teaching process. To minimize this confusion, we created a teacher's manual. The goal of this manual was to explain the operation of Google Cardboard and the VU Gallery app we had selected to display the VR component of the lesson. As English was not the native language of the intended audience, we formatted the manual as a list of instructions rather than prose. The manual contained directions for the teacher on how to prepare the hardware before the lesson. It also contained instructions to give to the students regarding starting and using the app to view 360 images as well as how to navigate between these images. A complete copy of this manual can be found in Appendix G: Teacher's Manual.

### 3.2.6 Conduct Teacher-in-Training Student Workshops

Once the lessons were finished, our sponsors set up a small workshop with students from a first year university geography class to evaluate the lesson before it was administered to the secondary school students. The workshop consisted of a presentation of the teaching package to the geography students and a survey to collect feedback from them (Appendix H: Teacher-in-Training Workshop Survey ). The feedback consisted of the geography students' opinions on whether they believed the lesson would help the students achieve the learning objectives, heighten the students' interest in the topic, and whether or not the geography students believed the lesson was feasible. The feedback gained from this workshop was analyzed to draw conclusions on barriers to entry of VR technology in the classroom.

## 3.3 Pilot Program Testing and Evaluation

Our sponsors selected and scheduled the class for our pilot program. Testing of the lessons occurred on two consecutive Saturdays; the secondary school students and teachers visited EdUHK in the morning. The students took the pretest immediately preceding the lesson, and then the students took the posttest immediately after the lesson.

### 3.3.1 Teacher and Class Selection Process

In order to assess the effectiveness of our program, we tested our package with two groups: a test group and a control group. Our sponsors chose the students, and one of our sponsors delivered the lectures to ensure the lesson was taught as intended. The students were selected from a pool of English speaking secondary school students. Two classes were selected based on availability and brought to the EdUHK. One of our sponsors presented our pilot VR lesson to one of the class sections. Another sponsor presented the 2D (control) version of our lesson to another class section. In addition, the two groups of students came from different schools. The control group received a modified lesson plan that uses reformatted, 2D versions of the 360 degree pictures as slides instead of through the VR headset. Furthermore, the control lesson contained the same information as the VR lesson.

### 3.3.2 Evaluations

To gather data about the effectiveness of our package, the students in each group took a similar pretest and posttest on the content of the lesson, as well as a survey of their opinions on the method of learning they received. The survey contained a set of Likert scale questions to assess the level of engagement and interest of the students (Appendix D: Survey for Students after Lessons). The surveys were administered directly by the teachers without any assistance from the project team.

We conducted our own observations of the lessons. We observed the lesson to see how the students were using the VR technology and their level of engagement with the material. We looked specifically for any difficulties that the students were having with the technology, as well as whether or not the students were becoming distracted by the technology. A copy of these observations sheets can be found in Appendix I: Lesson Observation Sheet.

### 3.3.3 Data Analysis

We compiled and tabulated the results from the pretests and posttests as well as on the experiential evaluation surveys. We looked to see if the improvements between the pre and post tests for the VR classes are significantly different from the improvements across the control classes. The students labeled their exams with their assigned student identification number. With these numbers, we were able to correlate each student’s pretest to his or her posttest. The scores of the exams from both classes were statistically analyzed in Microsoft Excel with a Student's T-Test, with an assumed p-value of 0.05. If the result of the T-Test was less than the assumed P value, we could state with 95% confidence that the two classes' improvement in scores were significantly different.

## 3.4 Conclusions and Recommendations

Once the analysis was complete, we compiled a set of conclusions and recommendations for our sponsors. Our report contained our analysis of the collected data as well as a summary of student responses and feedback from students and teachers on the VR's feasibility, and effectiveness in achieving the learning objectives. Our recommendations included additional steps our sponsors could take to collect more data using the materials and procedures we created as well as suggestions for further areas of investigation. We also detailed several suggestions regarding the application of VR technology for other topics in the geography curriculum.

# 4.0 Findings and Analysis

In this chapter, we discuss the curriculum and content for our lesson design. We chose to focus on only a few learning objectives for each topic. We then discuss our process in picture taking. Next, we discuss how we developed our lesson plans, pre/posttest, and lesson worksheets. Finally, we analyze the data that we received from the lesson, including change in test scores, and survey on the students' opinions.

## 4.1 Hong Kong Secondary Geography Curriculum

Our sponsors provided us with the Curriculum and Assessment Guide that states the secondary school knowledge for the topic of geography (Curriculum Development Council and The Hong Kong Examinations and Assessment Authority, 2015). The most recent revision of the Secondary 4-6 Geography Curriculum was implemented in 2015. The curriculum is divided into six topics spanning three sections. The time allotted to each topic varies to allow sufficient time to cover all the material given.

The first of the three sections in the structure is the Compulsory Part, which covers 68% (approximately 170 hours) of the total lesson time. The goal of this section is to assist students in acquiring the fundamental geographical concepts to develop a framework of thinking that is essential for further study. The Elective Part, accounting for 20% (approximately 50 hours) of lesson time, is divided into four electives in order to adapt to the various levels of aptitude, interests, and needs of the students. The fieldwork part, which is the remaining 12% (approximately 30 hours) of the lesson time, includes spatial data enquiry. The time allotted allows for both sufficient curriculum time and the necessary teachings for different out-of-classroom activities.

The Compulsory Part of the geography curriculum comprises seven key geographical issues and problems considered relevant for Hong Kong students. These issues were developed with the thought that they were expected to be public concerns within the foreseeable future. The topics are divided into three subsections: living with our physical environment, facing changes in the human environment, and confronting global challenges. We focused on two of the seven topics -- specifically *Managing Rivers and Coastal Environments; A continuing challenge* and

*Building a Sustainable City -- Are environmental conservation and urban development mutually exclusive*?

## 4.2 Lesson for Managing River and Coastal Environments: A Continuing Challenge

The river and coastal environments module aims to introduce the workings of fresh and seawater to create various landforms. This module describes these processes and how they change over space and time. For this lesson, we identified two key learning objectives that guided the development of our lesson: being able to identify coastal landforms and recognizing differences in wave types. These two learning objectives were selected because the sites that were chosen by our sponsors, High Island Reservoir and Tung Ping Chau, exhibit a variety of coastal formations due to their unique geology and coastal locations. Most of Hong Kong is geologically comprised of granite and volcanic rocks, whereas Tung Ping Chau is formed from sedimentary rock.

### 4.2.1 Coastal Environment Content

Coastal landforms are the result of centuries of coastal processes involving two wave types: constructive and destructive. While constructive waves favor deposition, the act of depositing material onto a shoreline, destructive waves cause the erosion of rocks and other materials along a coastline.

Waves are formed from ripples along the water. These ripples are the effect of friction with the wind. The energy of the wave is determined by the duration and speed of wind. Additionally, fetch is the distance over which a wave form. A longer fetch allows for a longer duration of wind, forming a larger wave. Waves that eventually break at the shoreline are called breakers. They have both a swash and a backwash. A swash is water that runs up the shore. The backwash is the water that is pulled back down the shore by gravity. Constructive waves have a stronger swash than backwash, which results in material being left on the shore. Destructive waves behave in the opposite way; the strong backwash pulls material from the shore. Destructive waves often have higher energy than constructive waves.

In areas where the land is significantly higher than the sea, erosion creates a variety of landforms, including sea cliffs, wave-cut platforms, sea caves, geos, sea arches and stacks.

Headlands and bays are formed along the coast in areas where the land has varying resistance to erosion in bands perpendicular to the coast. Sea cliffs and wave-cut platforms form when destructive waves erode the rocky headlands to form a notch. As the notch continues to erode, the rock above collapses. After this happens repeatedly, the wave-cut platform is formed with a sea cliff on the edge. Sea caves are often formed at headlands with varying resistance in the rock. The less resistant rock is eroded to form a tunnel. Geos are formed when the sea caves collapse, resulting in a valley. Sea arches are formed when sea caves on either side of a headland connect together over time. After continued erosion these arches may collapse to form a stack. The rock separated from the mainland is the stack (Figure 6).

*Figure 6. Photo of sea stack near High Island Reservoir*

Deposition also forms a variety of features such as beaches, offshore bars, spits, bay-bars and tombolos. Beaches are formed where constructive waves deposit large amounts of sediment.

The sediment is sorted into layers of sand, pebbles, rocks and boulders. Additionally, when bays and headlands are present, waves lose energy, resulting in the creation of constructive waves that push sediment onto pocket beaches, between two headlands (Figure 7). A spit of land is formed where longshore drift builds up sediment to extend a beach. Tombolos are bars that connect an island to the shore. A bay-bar is formed when a spit extends across a bay, closing it off to the rest of the sea and creating a lagoon. An offshore bar is a ridge of sediment deposited offshore, parallel to the coast.

*Figure 7. Photo of Long Ke Wan pocket beach (far left) with headlands (right)*

### 4.2.2 Coastal Site Selection and Image Collection

The sites for our project were areas selected by our sponsors, because they are relatively remote locations, making them ideal for a virtual field trip. At the sites themselves, there were also many different coastal landforms scattered within a small area. Many of the landforms described in the curriculum can be found at High Island Reservoir, including a sea cave, stack, rock folds and hexagonal rocks. For our coastal lesson, we collected many pictures of a sea cave by flying the drone into it as well as around the entrance. We took pictures of a sea stack by flying the drone at an altitude above the stack. North of the reservoir, a trail leads to a viewing location along the hill, where we obtained 360 photos of a long expanse of coastline, including many more sea caves, a geo and a pocket beach. The trail leads to the pocket beach, where we took more aerial photographs that showed the headlands and sea caves surrounding the pocket beach. Lastly we took a 360 degree video of the constructive waves on the beach.

Tung Ping Chau is an island in the north east of Hong Kong, close to mainland China. The coastal features around the island vary from beaches to cliffs to wave-cut platforms. We took 360 photographs across the island including Cham Keng Chau, Lung Lok Shui and Kang Lau Shek. Cham Keng Chau is in the north west of the island where a corridor splits the land. Lung Lok Shui or Dragon's Descent into Water is an example of rocks having layers with varying resistances to erosion. In this case the top layer was not as erosive, which results in what looks like the spine of a dragon entering the water. Kang Lau Shek features two sea stacks on wave-cut platforms.

*Figure 8: Photo of valley on Tung Ping Chau*

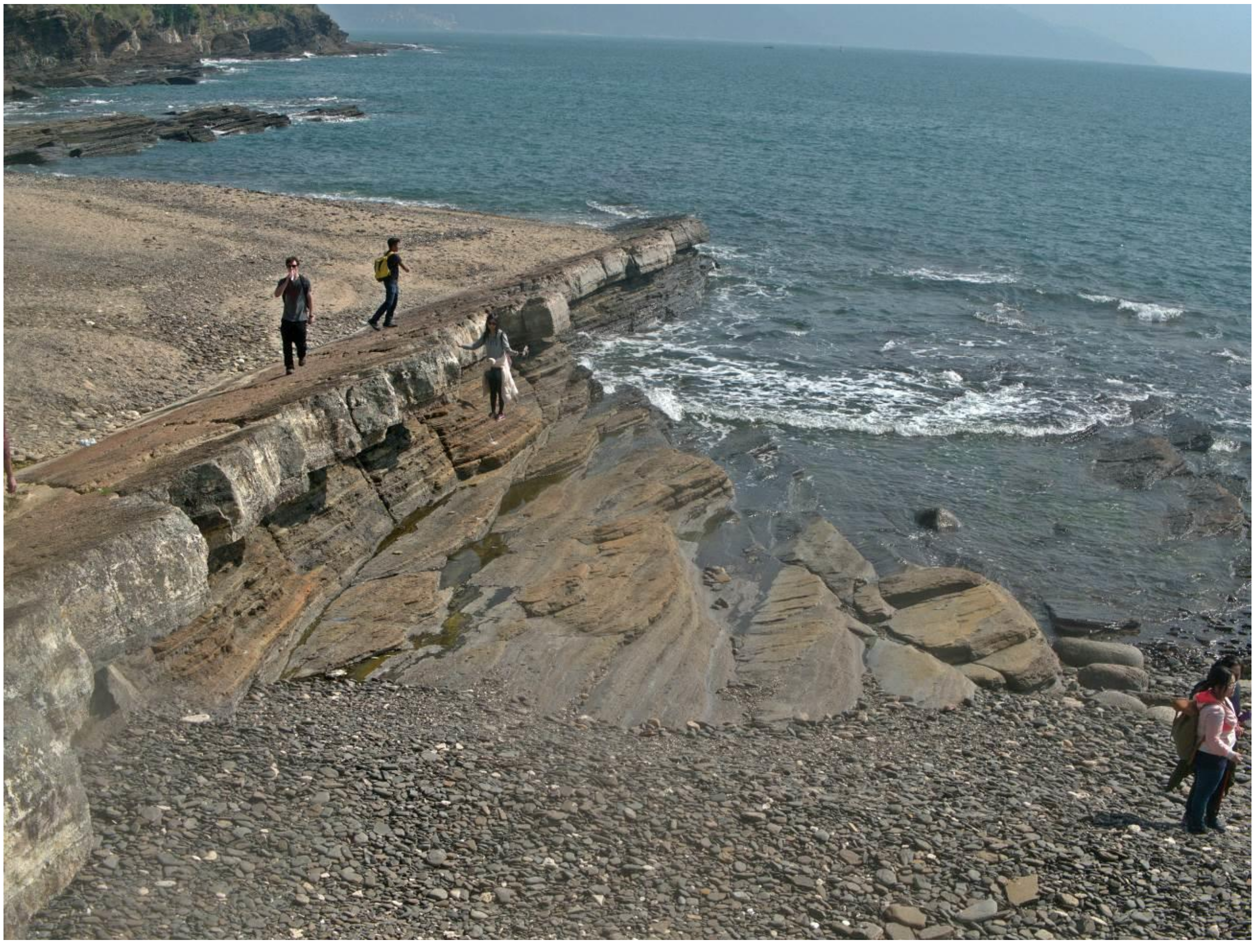

*Figure 9: Photo of Dragon's Descent Into Water on Tung Ping Chau*

*Figure 10: Photo of sea stack on Tung Ping Chau*

To begin the photo selection process, we first had a preliminary walkthrough of the two sites, Tung Ping Chau and High Island Reservoir to capture images of a few basic landforms, including sea stacks, collapsed sea caves, valleys, wave cut platforms, and sea cliffs. During this preliminary walkthrough, we scouted the areas and took as many pictures as possible, compiling a collection of several different coastal landforms that we used as test images for learning the software. We then drafted our lesson based on the content and narrowed down our photo selection process to fit the lesson content. From there, we created another list of key features we needed to include in the lesson, or did not have good pictures for, and returned to High Island Reservoir. Of the photos from the finalized selection, some photos were taken from the original walkthrough of each site. For the trip back to High Island Reservoir for additional pictures, our sponsors gave us some insight on where we should take the photos based on the selection of topics we were covering in our lesson. They suggested that we capture images at Long Ke Bay, near High Island Reservoir, to capture images of the bay and pocket beach, just north of the reservoir, with the drone.

### 4.2.3 Coastal Lesson Plan Development

Our coastal lesson plan was based on content from the textbooks (Lin, 2014; Ip, 2014) and lesson plan examples provided by our sponsors. The lesson plan examples provided us with the structure of a generic lesson plan. The lesson plan first lists the learning objectives. The rest of the lesson plan consists of topics, with the timings, teaching purpose, teaching activity, teaching process, and the resources used for each topic. The learning objectives were obtained from the curriculum for secondary school students on the topic of geography. In the lesson itself, we included the given content, in order to cover multiple levels of the Bloom’s Taxonomy, reaching the Understanding and Apply levels. The lesson also utilized various forms of media, consisting of basic text, diagrams, and images, delivered in the form of a PowerPoint presentation.

For the lesson design, we selected our topics based on the curriculum, taking into consideration both the content of the textbooks, as well as the selected sites. After a preliminary walkthrough of the sites had been finished, we compiled a lesson plan that included the coastal landforms found at the two locations and the related material covered in the textbooks. Once a basic idea of a lesson was formed, we organized the material in a logical order, presenting information about waves followed by descriptions of the coastal landforms and their formation processes. This showed the process of creating coastal landforms with a cause and effect relationship.

The worksheets served to act as guiding notes for the lessons. The worksheet was an amalgamation of several tables and descriptions found in the textbooks. It is split up into three sections to fit with our lesson plan, Wave Types, Major Coastal Processes and Landforms. The worksheets operate on mostly the Remember and Understand levels of Bloom's Taxonomy with one question reaching the Analyze level as we wish to draw connections between each of the coastal processes and how they flow into one another. Some parts of the worksheet operate as notes to supplement the slides. The worksheet (Appendix B: Coastal Lesson Worksheet) should help build up the students' knowledge and provide something to review after the lesson.

### 4.2.4 Assessment Materials

The pre-tests and post-tests were used to evaluate the students' knowledge of the subject material before and after the lessons were given. We derived the test questions for the coastal lesson from a question bank belonging to the Senior Secondary Exploring Geography (Second Edition) textbook (Ip, 2014). We chose questions that represented the level of knowledge of Bloom's Taxonomy covered in the lesson (Understanding and Apply levels). The questions were also chosen to allow the students to infer information that was not explicitly stated in the lesson. This allowed for more difficult questions that examined the students at a higher level of understanding. As per our sponsors request, these questions were multiple choice questions, and matching questions that followed our chosen learning objectives.

Our survey seeks to determine the attitudes of students when using VR as a virtual field trip. Huang et al. (2010) conducted a study on the attitudes of students using Virtual Reality Learning Environments. Huang et al. (2010) sought to identify some of the features in a virtual reality experience that may have an impact on learning: immersion, interaction, imagination, motivation and enhanced problem-solving capability. We adapted their study to collect some qualitative data on our lesson and how the students felt about using virtual reality as a substitute for field trips.

### 4.2.5 Pilot Lesson Observations

The VR lesson pilot was conducted at EdUHK with a group of 20 students from Saint Too Canaan College, a secondary school in Hong Kong, where English is the teaching medium.

The lesson was originally planned to be 45 minutes long, but it ended up reaching 90 minutes. During the lesson, the project team observed interactions between students and the technology and the use of this new technology during a lesson.

Our observations were limited due to the lesson being taught in Cantonese. This made it difficult to tell if the students were asking questions about content, how to use the VR, or talking about something off topic. However, during the VR sections of the lesson, students seemed to point out interesting things in the VR and tell their friends about it. During one such occasion, a student had noticed the drone in the picture and observed it for over a minute by looking straight up.

One notable observation that we made was the ease of learning the technology. While only viewing a photo through the headset four times, the students seemed to be able to set up the device by themselves by the end of the lesson. The first few times that the device needed to be set up, many students required help. This number dropped drastically after the students viewed the first image, and dropped even further after the second. This suggests that students would not require much instruction on use of the hardware and software.

*Figure 11: Photograph of Students Viewing VR Material (Courtesy of Professor Ault)*

We also observed how VR can be distracting. Many students continued to use the headsets once the lesson had moved on to lecture. Students talked with their classmates about what they saw while the teacher was lecturing as well. This suggests that VR may serve as a distraction, being that is very novel at this point in time. However, this could also be due to the scheduling of the pilot test, on a Saturday with an unfamiliar teacher.

Students were not prevented from using electronics or speaking during the tests and lesson. We observed students using their smartphones during the test and throughout the lesson, and also discussing answers with each other during both the pre-test and post-test. As such, the results of the exams may not be a valid representation of the learning gains from the lesson. More extensive observations can be found in Appendix J: Observations.

### 4.2.6 Traditional Lesson Observations

The traditional lesson was delivered to 10 students. These students came from three different schools, and varied significantly in age. One student (student number 8) identified himself as a Primary 5 student. We removed his score from all calculations. The lesson did not have a worksheet for the students to fill out during the lecture. Additionally, the pre/posttest used in the traditional lesson was not the same as the one used in the VR lesson. Also, the lesson was delivered by Mr. Cheung, whereas the VR lesson was delivered by Mr. Fok. Due to the significant differences between the virtual reality lesson and control group, we were not able to draw many conclusions by comparing the two lessons. However, during the traditional lesson, we did observe that the students were significantly less distracted in comparison to the VR lesson.

### 4.2.7 Assessment of Learning Gains

The pre- and post-test consisted of five questions. For the VR lesson, the average pretest score was 1.21 with a standard deviation of 0.85. The average posttest score was 2.68 (SD 1.25) for an average improvement of 1.47 (SD 1.12). One student arrived late and did not take the pre-test, and was therefore not included in the analysis.

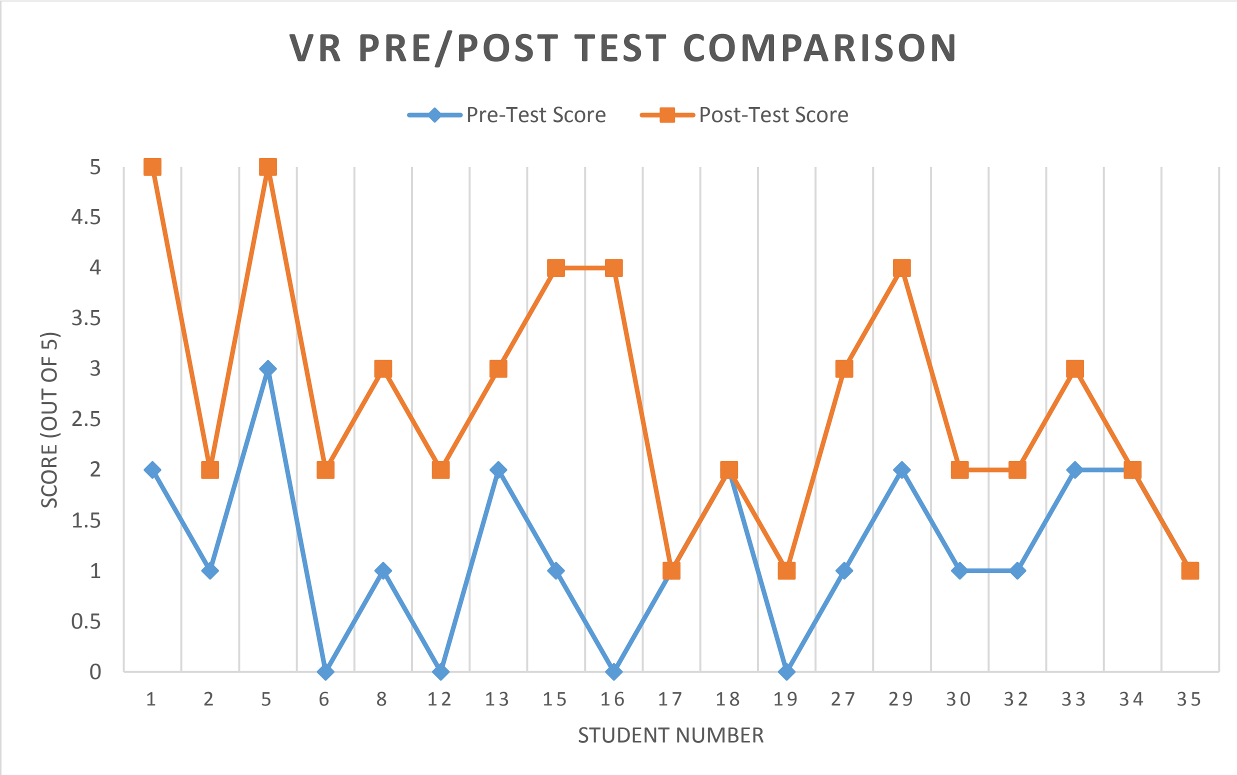


*Figure 12: VR Pre/Post Test Comparison*

A Student's T Test was done in Microsoft Excel between the student's pretest and posttest. The pre and post tests were statistically different, with greater than 95% confidence according to this calculation. For more detailed analysis, please refer to Appendix K: Pre/Post Test Results and Analysis.

The students who received the control lesson were given a longer test, containing 12 questions, but questions 1, 2, 3, 8, and 11 were very similar to the pre/posttest of the VR lesson. The average increase in score for these 5 questions by the students who received the traditional lesson was 1.70 with a standard deviation of 1.83. A Student's T Test showed that the traditional lesson's post test scores were statistically different from the respective pretest, with 95% confidence. These improvements were not statistically different from the improvements of the VR lesson. Please refer to Appendix K: Pre/Post Test Results and Analysis for more detailed analysis.

### 4.2.8 Virtual Reality Feasibility and Efficacy

Because of the inconclusive pre-test and post-test scores, our assessment is mainly focused on the feasibility aspect of VR. As such, the surveys we conducted with first year teacher-in-training students gave us insight into how feasible VR would be in a classroom setting, and they helped us to identify potential barriers with implementation of the technology. We were also able to assess the level of enjoyment the students got from the experience and their opinions on the effectiveness of VR for teaching a geography lesson.

Our survey for secondary school students shows that the majority of the students believe VR is a good tool for teaching geography. The students agreed with the majority of the Likert scale questions with the average of each question being close to 4 or higher on a 5-point scale where 5 is strongly agree and 1 is strongly disagree. There was very little disagreement between the students as all of the questions had a standard deviation less than one. Only one student seemed to prefer a traditional lecture and mentioned that s/he preferred to visit the site rather than seeing it in VR. The majority of the students agreed that the lesson was a helpful way to present the material and that it made them more interested in the topic. In addition, the students agreed that they would use this type of learning in the future if the option was provided. The responses were incredibly positive as the students were very excited about VR. When asked about their favorite part about the lesson, many answered that it was using VR. As such, the students seem to be very accepting of the technology in the classroom. For more detailed analysis, please refer to Appendix L: Secondary School Student Survey Responses

The university teachers-in-training seem to agree that while VR may be a useful tool for geographical education, they did not feel that VR would be adequate to use as a field trip alternative. Of the 26 teachers-in-training surveyed, when asked to rate the usefulness of VR in teaching geography, the teachers-in-training answered, on average, 4.35 (SD 0.69), on a scale of 1 = strongly disagree to 5 = strongly agree. They also believed that the lesson content was well suited for the VR module, scoring 4.19 (SD 0.63). However, when asked if VR could potentially substitute a field trip, the student teachers rated the idea 3.46 (SD 1.24). The data show that most teachers-in-training agree that geographical education is an adequate application for VR, but that it cannot replace a traditional field trip. (Appendix M: Teacher-in-Training Student Survey Responses)

In regards to the experience itself, the teachers-in-training viewed the experience positively. When asked if they enjoyed the experience, 24 of the 26 respondents either agreed or strongly agreed. Similarly, these teachers-in-training also perceived the experience to be highly immersive and that the quality of images and the images taken from a high vantage point were beneficial. Twenty of the respondents either agreed or strongly agreed that they felt immersed in the environment, and 21 either agreed or strongly agreed that they enjoyed the images taken from a higher vantage point.

Additionally, the teacher-in-training students were relatively neutral in regards to the potential barriers of VR. For instance, when asked whether or not they believed that a VR lesson would take too much time to prepare, with a score of 3.04 (SD 0.96). Interestingly, the scores for this question differed for male and female responses. The female students scored on average about 0.75 lower than their male counterparts. The same gender difference was shown when the teachers-in-training were asked if they believed they would have enough time to collect the VR content. In addition, teachers-in-training who had prior VR experience were neutral (responses averaged an answer of 3) about whether or not they would have sufficient time to prepare a lesson of this nature, while the students without prior VR experience believed they would not have time to prepare a VR lesson. Similarly, when asked if the expense of implementing this technology was too high, the teachers-in-training gave a score of 3.00 (SD 0.69). In terms of technical issues, the student teachers mostly agreed that secondary school students using the VR technology would be able to use the technology with ease, rating the simplicity of using the technology as 4.15 (SD 0.61). Likewise, when asked to rate the level of difficulty of using the software and hardware, most respondents agreed or strongly agreed that the two were easy to use. However, they disagreed with the idea of schools being able to provide technical support of the technology, giving the question 2.50 (SD 1.10).

Overall, the general consensus of the surveyed student teachers was that while VR could potentially be beneficial to geographical education, it should not be an alternative to field trips. However, the use of VR in a classroom setting to teach geography concepts appears to be feasible. The student teachers did not experience any technical barriers, involving hardware and software, but they were concerned about the time to gather content material and prepare lessons, as well as the availability of technical support schools could provide and the issue of cost.

## 4.3 Lesson for Building a Sustainable City – Are Environmental Conservation and Urban Development Mutually Exclusive?

The second lesson we developed focuses on another of the seven compulsory key issues and problems of the Geography curriculum considered relevant for Hong Kong students, specifically, *Building a Sustainable City --Are environmental conservation and urban development mutually exclusive?* This portion of the curriculum examines the reasons why cities like Hong Kong continue to grow and the problems and conflicts associated with such growth. The curriculum also presents the concept of sustainable development, along with the question of how the economic health of a city can be maintained without sacrificing environmental quality (Curriculum Development Council and The Hong Kong Examinations and Assessment Authority, 2015).

For our lesson we identified three key learning objectives that guided the development of our lesson plan: being able to identify urban problems, being able to explain what factors cause these problems and developing an awareness of how people are affected by these problems. These three learning objectives were developed based on the curriculum and input from our sponsors. These topics were also ideally suited for study using a virtual field trip, since 360 photos allow students to explore and identify urban problems and their solutions visually.

### 4.3.1 Urban Development Content

The content for the urban problems lesson was based on the content found in Senior Secondary Exploring Geography (Ip, 2014) which we were given by our sponsors as a guide to the secondary school curriculum. The concepts and terminology for the lesson were also taken from this source as well as New HKDSE Interactive Geography (Chau, 2014).

A rural village can grow into an urban city. The changes associated with this growth can be described through the process of urbanization. Certain predictable steps occur in this process: urbanization, suburbanization, counterurbanization, and reurbanization. The sub-processes involved in these steps are urban decay, urban encroachment, and urban renewal. Each stage and sub-process contributes to various urban problems in a developing city.

Urbanization can be defined as the growth of urban development in a region. This increase in infrastructure and industry in the region acts as a pull factor to draw in additional inhabitants as people migrate in from rural areas. Overpopulation can occur when rapid population growth exceeds the development of housing. Urban decay can be defined as the physical decay of buildings. This decay can be caused naturally by the passage of time for older buildings or result from overpopulation in the city. Overpopulation causes an imbalance in supply and demand, which leads to illegal, sub-standard housing and increased rent with little to no incentive for building maintenance. The rapidly changing needs of a developing city also cause land use conflicts to arise, causing vastly different businesses to be found on the same block. In Hong Kong, the rapid growth that came with urbanization led to the development of New Kowloon, in order to provide enough space for the increased population in Kowloon (Ip, 2014).

Suburbanization, on the other hand, is the outward movement of people from urban areas to suburbs in response to overpopulation pressures. In Hong Kong, this can be seen in the development of new towns. Currently, many of the people who live in these newer towns commute to the more urban areas. As more people commute from the suburban communities to the urban communities, traffic congestion increases significantly, lengthening the commute of residents and straining transit routes. Additionally, urban encroachment happens when a city expands outwards into land that was previously rural. However, this transformation does not necessarily transform the encroached area into full urban centers. Suburbanization is an example of urban encroachment as the new towns in Hong Kong were built on previously rural land.

Counterurbanization is a more extreme decentralization process where people relocate to rural areas to escape the city pressures. Excess consumption of resources is also an issue, as even though residents need resources, consumption also generates a large amount of waste. This large amount of waste not only produces pollution, but also consumes space in landfills. Construction of more landfills increases urban encroachment.

These urbanization problems pose a serious threat to the city in the near future, in addition to longer term problems such as climate change. Urban renewal attempts to resolve these issues. Urban renewal involves the government repurchasing land in order to rebuild and renew the area. The government can then redesign the area to suit the updated needs of the developed city. This redesign can include changing the layout of the buildings, streets, and walkways to help cull the traffic problems, rezoning city blocks to create more distinct residential, market, and industrial areas, or upgrading older buildings with more advanced technology such as elevators and temperature regulation. It also usually involves the construction of more high occupancy housing than originally available. The resulting revitalization can lead to reurbanization as people forced out of the city center by high rent prices and overcrowding move into the renovated area and newly available housing.

### 4.3.2 Urban Site Selection

Since the purpose of the urban lesson plan was to explore problems and solutions associated with the urbanization of Hong Kong, it was very important to select appropriate locations to support this goal. We selected Mong Kok as our site to explore three urban problems in depth, (specifically traffic congestion, mixed land use and substandard living conditions) and City One - Shatin as the site to demonstrate solutions to these three urban problems. This decision to focus on these three specific problems and use these two sites was not our original plan, but was reached based on a filtering process and feedback from our sponsors.

Monk Kok is a densely populated area on Hong Kong located in the western part of the Kowloon Peninsula in the Yau Sim Mong District. Mong Kok is filled with both old and new multistory and multipurpose buildings used for both residential and commercial use. It has a long history of urbanization and is a popular shopping area. Because of its growth, many of the problems described in the geography curriculum can be found in Monk Kok, including the problems we selected to focus on in the lesson.

In contrast, City One - Shatin Town is a much smaller, newer, government-planned, private residential housing estate located in Sha Tin, New Territories. It was built in the 1980s on reclaimed land and consists of over fifty blocks of tall residential buildings. It is a good example of sustainable development. For these reasons, most of the urban problems that exist in Mong Kok are not present in City One - Shatin.

The 2D and 3D photo selection process for the urban lesson plan began similarly to the coastal lesson plan photo selection process. Our sponsors suggested three sites that were likely to have the urban problems we needed to photograph. The sites were: Kwun Tong, Sham Shui Po and Mong Kok. We performed initial walkthroughs of all of these sites. On these initial walkthroughs we took pictures of every potential urban problem site we came across using both 2D and 3D photography. We used this shotgun approach for three reasons. The first was to determine what types of urban problems were easily photographed in ways that highlighted the problems as well as how best to take those photos. The second was to create a digital record of each potential photography location using a combination of the photo and our geotagging system so that could easily return to a site if we wanted to take more photos. The third reason for taking as many pictures as possible was to give ourselves as much information as possible when selecting and returning to a site.

The types of urban problem we were searching for, at this point, included poorly maintained buildings, mismatched businesses located next to each other such as heavy construction and restaurants, and intersections or roads with high levels of traffic congestion.

After reviewing all the photos we gathered in our initial walkthroughs, we determined that Mong Kok had the highest concentration and spread of different type of urban problems. Mong Kok also contained several areas that were either new or had been recently renovated. At this time, we also felt that Mong Kok might also be able to showcase solutions to some of the urban problems, and thus would be a good site to select for the urban lesson plan.

Also our original plan for the urban lesson was to find a pair of appropriate photos (both 2D and 3D) for each identified urban problem. One of the photographs would demonstrate and highlight that specific urban problem while the other photograph would be taken somewhere in the same site where the specific problem was not present and attempt to show how it had been addressed or solved.

After most of the photos had been collected from the Mong Kok area, we received some feedback from our sponsors with regards to our coastal lesson. They told us we should reduce the number of 3D photos we intended to include in that lesson in order to allow students sufficient time to explore each photo during the allotted time for the lesson. This instruction changed our plan for the coastal lesson as well as for our urban lesson. We searched through the photos again and attempted to find a single photo that could be used to highlight three urban problems and a single photo that could be used to highlight solutions to those three urban problems. There were plenty of photos from Mong Kok that highlighted multiple problems; however, while we had photos of solutions to individual problems, we were unable to find a location in Mong Kok to photograph that displayed solutions to all three problems in one location.

After more research, including searching maps and consulting with our advisors, we reasoned that City One - Shatin may be a site where we could find the single photograph we needed, and thus would be an ideal site to demonstrate solutions to our three selected urban problems. This reasoning was made based on the fact that City One – Shatin is relatively new and well-laid out with large areas of dedicated residential complexes, so there was the opportunity to find multiple urban problem solutions in the one location. Again, this was a situation we were unable to find and photograph in Mong Kok. We travelled to City One – Shatin and took several 2D and 3D photos, based on the criteria. Though we set out to find one site for the urban lesson plan, we ended up selecting and using two – Monk Kok to showcase our three selected urban problems and City One – Shatin to showcase our solutions.

The final image we selected from Monk Kok contained examples of traffic congestion, mixed land use and substandard housing as the urban problems we were highlighting in the lesson.  The final image we selected from City One – Shatin showed a pedestrian overpass, an MTR station, and a well maintained private housing high-rise. These each demonstrate possible solutions to the urban problems displayed in the Mong Kok image that we could suggest in the lesson. These images can be seen in (Appendix N: Urban Lesson Materials).

### 4.3.3 Urban Lesson Plan Development

As stated previously, the content for the urban lesson plan was taken from Senior Secondary Exploring Geography (Ip, 2014) which serves as the textbook for this section of the curriculum. The book covers the urbanization cycle and its steps (urbanization, suburbanization, counter-urbanization, and reurbanization), as well as the urban problems that present themselves during each of these stages.

As discussed in this textbook, urban problems are complex concepts and sometimes difficult to explore in single images. We thought that VR's ability to immerse the viewer in an entire environment might help to convey these complex concepts to students.

The form and structure of the urban lesson plan was based on that of the coastal lesson. The lesson begins with the learning objectives and also consists of topics, lesson timings, teaching purpose as well as the activity used and resources required to complete the activity. Each learning objective was designed to address sequentially higher levels of Bloom's taxonomy; progressing from identifying urban problems on the first level through identifying the causes of these urban problems on the second level and finally developing an awareness of how people affect and are affected by various urban problems. The design follows a general framework of introducing students to some concepts and background then allowing them time to come to their own conclusions before describing solutions. By making students think about a problem and its solution before giving the solution, students are better able to grasp the problem so that they better understand the solution when it is presented to them (Brown, 2017).

The lesson also utilized a range of media consisting of basic text, diagrams and images delivered in two PowerPoint presentations, one using 3D pictures and the other 2D pictures. A worksheet was also part of the lesson to help enhance the lesson. A worksheet was also designed to help achieve the lesson's three learning objectives. The worksheet consists of the guiding questions present in the PowerPoint lesson as well as places for students to take notes and record their answers. The answers for same guiding question for each picture are recorded side by side. This formatting allows students to compare and contrast their answers for urban problems and associated solutions to those problems (Appendix N: Urban Lesson Materials).

### 4.3.4 Assessment Materials

To test the students' knowledge of the lesson subject material before and after receiving the lesson, we developed pre- and post-tests (Appendix N: Urban Lesson Materials). From the bank of questions provided by our sponsors we selected six questions that matched our three chosen learning objectives. These multiple choice and matching questions were designed to test students on multiple levels of Bloom's taxonomy. The first level questions involved identifying terms related to the lesson plan content. These questions call on the students' rote memorization and recall. The second level of questions involve material covered without ever going over the answers to the questions directly. These questions require the students to understand the material well enough to draw simple conclusions. Due to time constraints, the urban lesson plan was not pilot tested.

# 5.0 Conclusions and Recommendations

In this project, we created two versions of the same lesson: one using VR technology and one traditional lesson. Our sponsors then administered these lessons to two groups of students. A similar pretest and posttest were administered, allowing us to gauge the students' learning of the subject material. Additionally, we asked the students to fill out a survey regarding their opinions on the lessons that they received (both VR and traditional). Due to the differences between the two lessons, we were unable to formulate any conclusions of effectiveness by comparing the exams from both lessons. However, our findings do suggest that VR is a feasible tool for use in education.

## 5.1 Recommendations

In this section we will discuss recommendations relating to the collection of content and development of additional lessons. We also recommend strategies for additional pilot testing of VR in geographical education.

### 5.1.1 Lesson Design

**We recommend that teachers emphasize the immersive experience when planning a VR lesson.** Although the lesson content itself should be the main priority, the 360-degree VR images create a highly immersive experience and should be utilized in that manner. For example, by first allowing students to explore a 360-degree image, they become more engaged with a topic and can attempt to learn on their own from their surroundings. On the other hand, a traditional lesson, which only features flat images, provides less sensory engagement that may not demand as much student involvement.

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### 5.1.2 Recommendations for Content and Lesson Development

**Content developers should plan the content collection using a list of desired photos, and at least one person on the team should have some knowledge of photography.** A list of photo shots with a description, purpose, and any extra information, such as time of day, weather or tide, will provide a structure to the image collection, and help prevent the need for multiple visits to the collection sites. In addition, it will aid in the capture process as the photographer can approach the subject knowing the purpose of each shot. The creation of the list will also assist in clarifying the details of the lesson. Having a clear purpose for each image will allow for creativity in how to accomplish the purpose. One example of this would be choosing to take a picture during rush hour to show traffic problems. Even basic knowledge of photography can provide better quality images. For example, when capturing images, multiple shots should be taken. Trying different angles with various settings will improve the final product as there will be a variety of shots from which to choose. More advanced photographers will have more techniques for taking pictures.

### 5.1.3 Classroom Management

**We suggest to our sponsors, in their future research of this topic, to increase their classroom management of experimental lessons.** From our observations, we noticed that VR can be distracting to students. This might bias the test results if students are not using the VR device as intended by the teacher. Additionally, we observed many other distractions in the classroom. These distractions included students talking amongst themselves and using their personal mobile devices. These issues could influence the posttest scores of the students, as they may miss information in the lesson, look up information, or share answers during the test.

One way to avoid the distraction of VR in the classroom would be to limit one VR headset to a group of about four to five students. This would prevent any one particular student from becoming distracted by the technology, and would also promote a group learning environment.

Additionally, for a virtual reality lesson, the teacher should allocate sufficient time for the students to learn to use the technology. We noticed that although the students were able to grasp the technology on their own after several attempts, their first experience with the virtual reality headset was rather troublesome. Many of the students did not know how to operate the devices and required the assistance of the teacher, which took a lot more of the lesson time than anticipated.

### 5.1.4 Observations

**We recommend to our sponsors to analyze students' engagement in the VR lessons to a much more quantitative level.** This can be done by observing students' behavior during a lesson, such as number of times looking at the clock, number of times using their electronic devices, etc. Those numbers can be tallied and compared to multiple different classes. This type of analysis would provide a stronger argument that VR is helpful in achieving a deeper level of emotional involvement, as described in Bloom's Taxonomy.

### 5.1.5 Hardware and Software

**We recommend that our sponsors acquire new hardware and research available software.** According to the survey responses from the teachers-in-training, many people found the headsets that we used caused them to feel sick or disoriented. In our personal observation of the hardware, we noticed a similar feeling. It was difficult for anyone in our group to view a photo in the headset for longer than a minute. In our testing, we found other Google Cardboard viewers to be more comfortable and provide better image quality. As such, we recommend testing other devices and acquiring a better Google Cardboard viewer. Additionally, we suggest finding software that allows the teacher to control the mobile devices. Allowing the teacher to lock the device to the current application and remotely change photos or disable viewing would prevent students from getting lost in the software and prevent distraction from the headset.

### 5.1.6 Additional Pilot Studies

**We recommend that the researchers at EdUHK complete more extensive studies on the use of VR in the geography curriculum.** As this was only a pilot test, the data received from the evaluations are not conclusive. Our study only evaluates the *feasibility* of using virtual reality as a substitute for one field trip. We were unable to measure the *effectiveness* of virtual reality as a substitute field trip. In addition, our study only compares a virtual reality lesson to a traditional lesson. To properly evaluate virtual reality as a substitute for field trips, it must be compared directly to a traditional field trip. More extensive use of VR within an entire unit of geographical education (such as coastal or urban environments) would provide data on other content areas, as well as a longer term analysis and the potential to measure long term retention.

With more than one lesson, students would become accustomed to the VR hardware and software, and would be less likely to be distracted by the novelty of the experience.

Additionally, Virtual Reality can be used in multiple ways in geography. In our case we used VR as an additional tool in the lesson. Research should also be done on virtual field trips, which could be used as a substitute for traditional field trips. Self-guided modules are another potential application of virtual reality. Self-guided modules would allow students to download and view the content and follow a guide at their own pace. This could potentially serve as homework. We recommend researching the feasibility and effectiveness of a self-guided module.

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| 2.0 | Literature Review | Anthony Chan | All |
| 2.1 | Technology in Education | Anthony Chan | All |
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# Appendix A: Lesson Plans

**Virtual Reality Coastal Lesson**

Objectives

- Identify coastal landforms.
- Explain how waves create coastal landforms.

| Duration | Teaching Purpose | Teaching Activity | Teaching Process | Resources |
|---|---|---|---|---|
| 10 minutes, immediately preceding the lesson | Pretest examination | Administer pretest | 1. Allow students to complete the pretest on coastal landscape | • Pretest |
| 5 minutes | Explain how to use VR Technology | | Using PowerPoint, quickly run through how to set-up the headset, view pictures, and navigate through the media. | • PowerPoint |
| 16 minutes | Learn the difference between wave types and how they are formed | Show 360 degree pictures | 1. Allow students time to view Photo 1 in VR<br>2. Short description of waves<br>a. Wave Types<br>b. Fetch (Photo 2)<br>3. Have students fill out worksheet as they learn answers from lecture | • PowerPoint<br>• Photos<br>○ Photo 1 (JI)<br>○ Photo 2 (TPC)<br>• Worksheet |
| 17 minutes | Learn the different landforms and how they are formed | Show pictures, group discussion | 1. Headlands & bay, pocket beaches (Photo 3)<br>a. Look for landforms<br>2. Discuss/lecture on Erosional Landforms | • PowerPoint<br>• Photos<br>○ Photo 3 (LKW)<br>○ Photo 2 (TPC)<br>• Worksheet |

| | | | | |
|---|---|---|---|---|
| | | | 3. Photo 2<br>a. Look for landforms<br>4. Identify the landforms: cliff, sea cave, arch, stack, wave-cut platform. | |
| 5 minutes | Conclusion and Recap | | 1. Recap the topics of waves and landforms | |
| 10 minutes, immediately after the lesson | Posttest examination | Administer posttest | 1. Allow students to complete the posttest on coastal landscape | • Posttest |

**Traditional Coastal Lesson**

Objectives

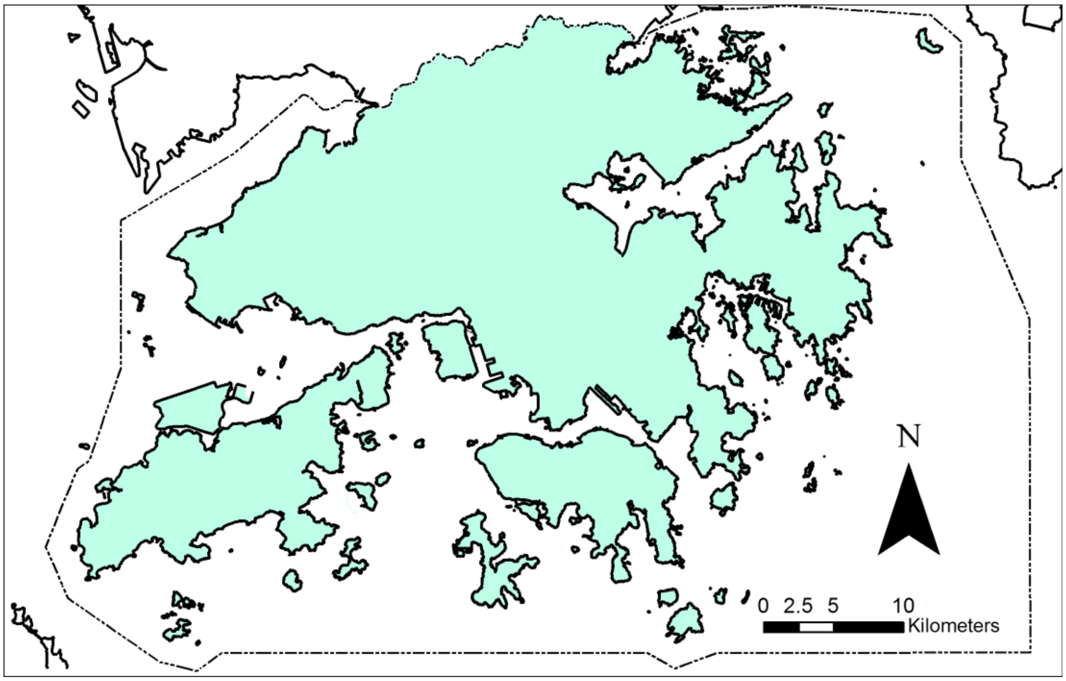
- Identify coastal landforms.
- Explain how waves create coastal landforms.

| Duration | Teaching Purpose | Teaching Activity | Teaching Process | Resources |
|---|---|---|---|---|
| 10 minutes, immediately preceding the lesson | Pretest examination | Administer pretest | 1. Allow students to complete the pretest on coastal landscape | • Pretest |
| 2 minutes | Raise students interest in | Ask questions | 1. Questions:<br>a. What is the major force to the formation of different coastal environment? | |
| 16 minutes | Learn the difference between wave types and how they are formed | Present PowerPoint | 1. Short description of waves<br>a. Constructive vs Destructive<br>b. Fetch, wind speed<br>c. Offshore gradient | • PowerPoint |
| 17 minutes | Learn to identify the different landforms and explain how they are formed | Present PowerPoint, group discussion | 1. Description of sea stacks, wave-cut platforms, pocket beaches, cliffs, sea caves etc.<br>2. Discuss as a class how the students think certain structures are formed, while looking at photos. | • PowerPoint |
| 5 minutes | Conclusion and Recap | | | |
| 10 minutes, immediately after the lesson | Posttest examination | Administer posttest | 1. Allow students to complete the posttest on coastal landscape | • Posttest |

# Appendix B: Coastal Lesson Worksheet

<u>Worksheet</u>

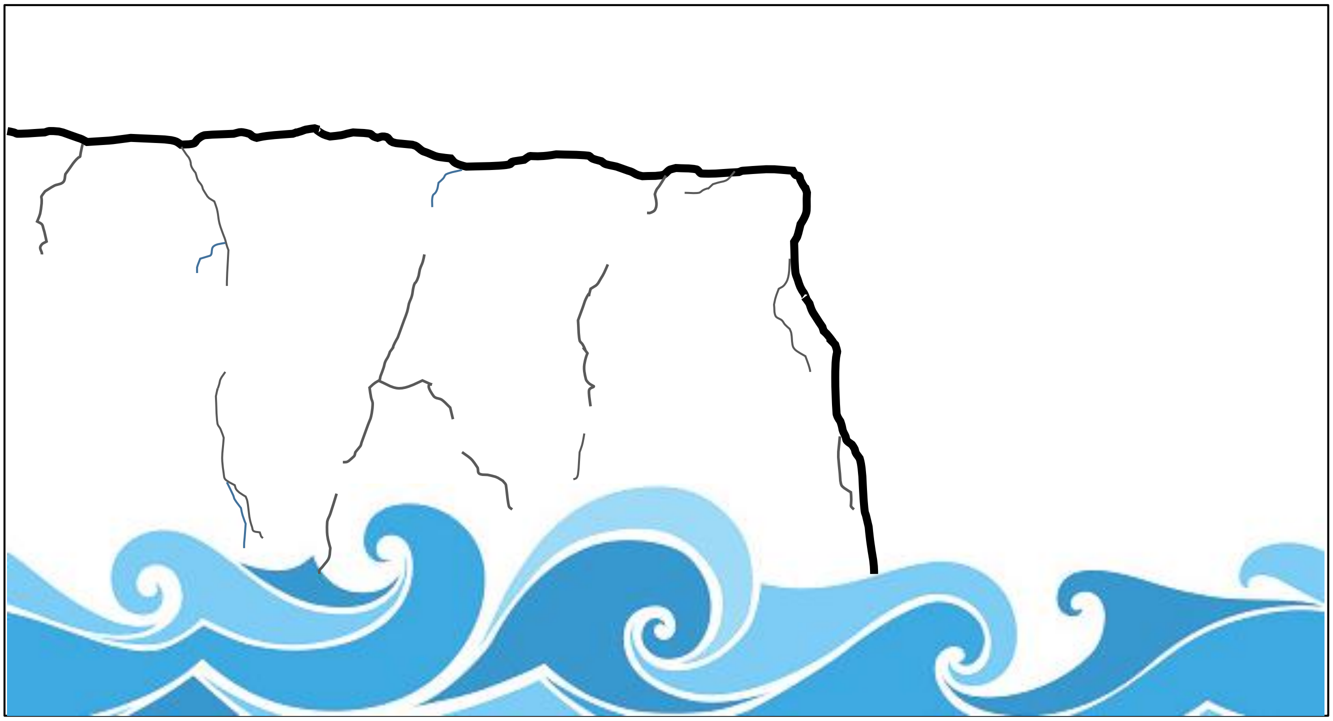
1. In the map, mark the three locations you observed through VR.




2. Complete the following table using the information provided from the lecture.

| Name of feature | Type of landform | Is it Erosional / Depositional? |
|---|---|---|
| **Tiu Chung Chau** | | |
| **Keng Lau Shek, Tung Ping Chau** | | |
| **Long Ke Wan** | | |
| **Lan Kwo Shui** | | |
| **High Island East Dam** | | |
| **Po Pin Chau** | | |

3. Complete the schematic diagram of coastal erosional landform below and label the features.



# Appendix C: Coastal Pre/Post Tests

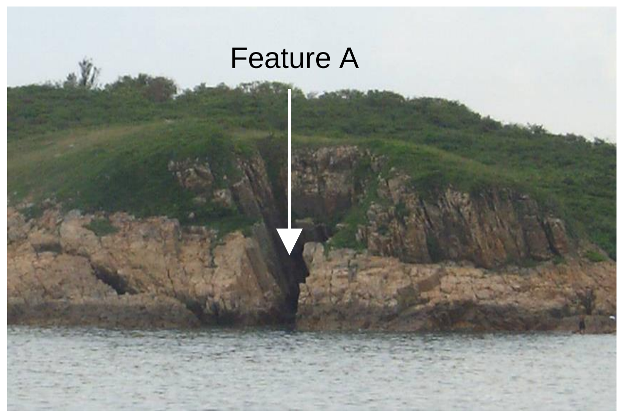
Class Number: _____________

Pre Test for Coastal Environment Lesson

There is only one correct answer for each question. Please circle the correct answer [A or B or C or D]

1. Which of the following descriptions about Feature A shown in the photograph to the right is correct?

   A. It is formed by deposition
   B. It is a sea arch
   C. It is found in a sheltered bay
   D. None of the above




2. Which of the following factors affect the energy of waves?
   i. Fetch length
   ii. Type of rock forming the shoreline
   iii. Typhoons
   iv. Depth of water

   A i and iii only    B iii and iv only    C i, ii and iv only    D i, iii and iv only

3. Which of the following description about waves is correct?
   A. They are caused by winds blowing across the sea.
   B. They only create erosional landforms.
   C. Their energy is concentrated at beaches.
   D. They gain energy when they came into shallow sea.

4. Refer to the photograph below. Which of the following comparisons between Places X and Y are <u>correct</u>?


| | X | Y |
|---|---|---|
| i | It is affected by destructive waves. | It is affected by constructive waves. |
| ii | Coastal erosional features are found. | Coastal depositional features are found. |
| iii | Offshore gradient is gentle. | Offshore gradient is steep. |

A ii only B i and ii only C i and iii only D all of the above

5. Refer to the photograph below. What is the correct sequence for the formation of Feature X?

i. Wave erosion cuts through the headland to form a sea arch.
ii. Wave erosion concentrates at lines of weakness on headland.
iii. Lines of weakness on headland are widened and deepened by wave erosion to form a cave.
iv. Erosion causes the roof of the sea arch to collapse, leaving a rock out in the water isolated from the headland.

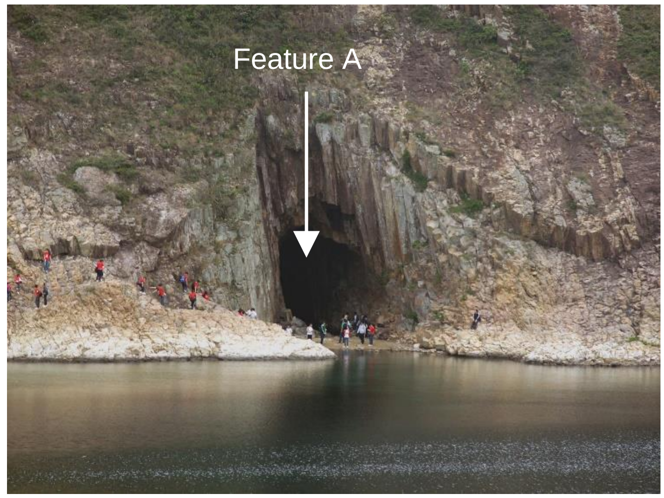

A ii→i→iv→iii B ii→iii→i→iv C iii→ii→i→iv D iii→i→ii→iv

Post Test for Coastal Environment Lesson

There is only one correct answer for each question. Please circle the correct answer [A or B or C or D]

1. Which of the following descriptions about Feature A shown in the photograph to the right is correct?

   A. It is a sea cave
   B. It is formed by wave erosion
   C. It occurs along a sea cliff
   D. All of the above




2. Which of the following factors affect the energy of waves?
   i. Fetch length
   ii. Type of rock forming the shoreline
   iii. Earthquake magnitude
   iv. Depth of water

   A i and ii only B i and iv only C ii and iii only D iii and iv only

3. Which of the following description about waves is <u>correct</u>?
   A. They are caused by ocean currents.
   B. They can create depositional landforms.
   C. Their energy is weaker at headlands.
   D. They lose energy with increased fetch length.

4. Refer to the photograph below. Which of the following comparisons between Places X and Y are correct?


| | X | Y |
|---|---|---|
| i | It is affected by constructive waves. | It is affected by destructive waves. |
| ii | Coastal erosional features are found. | Coastal depositional features are found. |
| iii | Offshore gradient is steep. | Offshore gradient is gentle. |

A iii only B i and ii only C ii and iii only D all of the above

5. Refer to the photograph below. What is the correct sequence for the formation of Feature X?

i. Wave erosion cuts through the headland to form a sea arch.
ii. Wave erosion concentrates at lines of weakness on headland.
iii. Lines of weakness on headland are widened and deepened by wave erosion to form a cave.
iv. Erosion causes the roof of the sea arch to collapse, leaving a rock out in the water isolated from the headland.


A ii→i→iv→iii B ii→iii→i→iv C iii→ii→i→iv D iii→i→ii→iv

# Appendix D: Survey for Students after Lessons

These questions were partly designed by modifying questions from Huang, *et al.* (2010)

Class Number: __________

Post Lesson Survey (VR)

(Please Circle One)

| | |
|---|---|
| 1. I enjoyed the lesson. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 2. This lesson was a helpful way to present the material to me. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 3. The lesson made me more interested in the topic. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 4. The lesson made me more motivated to learn about the subject. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 5. I would use this type of learning in the future if the option was provided. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 6. The experience enhanced my learning capability. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 7. The experience was realistic. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 8. The experience made my learning easier. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 9. The lesson helped me to be more engaged with the material. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 10. I believe that virtual reality is a good learning tool for environmental education. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |

| |
|---|
| 1. What was your favorite part of the lesson? |
| 2. What was your least favorite part of the lesson? |
| 3. What would you change about the lesson? Why? |
| 4. Any other comments? |

Class Number: ___________

Post Lesson Survey (Traditional)

(Please Circle One)

| | |
|---|---|
| 1. I enjoyed the lesson. | Strongly Disagree ... Strongly Agree<br>1---------2---------3---------4---------5 |
| 2. This lesson was a helpful way to present the material to me. | Strongly Disagree ... Strongly Agree<br>1---------2---------3---------4---------5 |
| 3. The lesson made me more interested in the topic. | Strongly Disagree ... Strongly Agree<br>1---------2---------3---------4---------5 |
| 4. The lesson made me more motivated to learn about the subject. | Strongly Disagree ... Strongly Agree<br>1---------2---------3---------4---------5 |
| 5. I would use this type of learning in the future if the option was provided. | Strongly Disagree ... Strongly Agree<br>1---------2---------3---------4---------5 |

| |
|---|
| 1. What was your favorite part of the lesson? |
| 2. What was your least favorite part of the lesson? |
| 3. What would you change about the lesson? Why? |
| 4. Any other comments? |

# Appendix E: 360 Degree Photos

Below are the three 360 degree images used in the VR lesson.

1. Sea Arch

2. Pocket Beach/Headlands/Bay

3. Wave-cut Platform/Sea Stacks/Cliff

# Appendix F: PowerPoint Slides

Coastal VR Powerpoint Slides

# COASTAL ENVIRONMENT

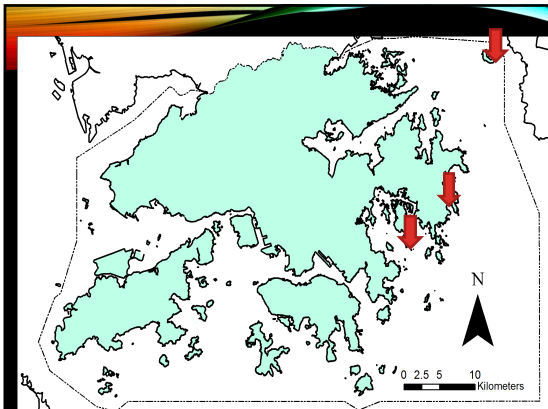
Lincoln Fok

## COASTAL LANDFORMS

- Virtual field trip
  - Jin Island (JI) 吊鐘洲
  - Tung Ping Chau (TPC) 東坪洲
  - Long Ke Wan (LKW) 浪茄灣
- How were these landforms created?

## VIRTUAL FIELD TRIP THROUGH VR

1. Open Google Cardboard APPS in the mobile phone provided
2. Click Cardboard Camera
3. Choose the top photo (with a boat)
4. Click the headset button in the lower middle
5. Start your visit
6. Change a photo using the button on the top right of the headset




## WHAT DID YOU SEE?

- Sea Arch 海蝕拱
- Wave Cut Platform 海蝕平台
- Sea Stack 海蝕柱
- Beach 海灘
  - Sandy

## COASTAL LANDFORMS

Erosional 侵蝕

- Cliff
- Notch 海蝕凹地
- Sea Cave 海蝕洞
- Geo 海蝕隙
- Sea Arch 海蝕拱
- Sea Stack 海蝕柱
- Wave Cut Platform 海蝕平台

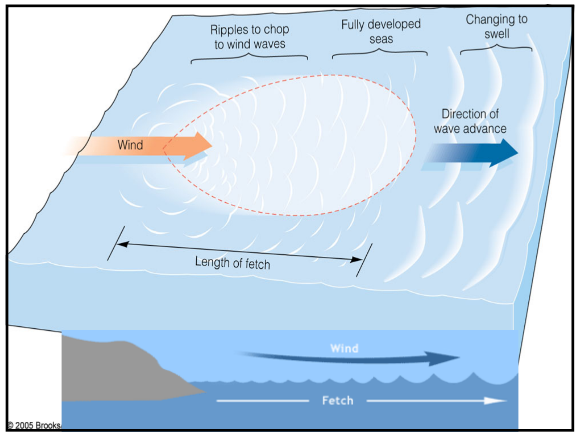
Depositional 沉積

- Beach 海灘
  - Mud flat - Sandy – Boulder
- Sandspit 沙嘴
- Bar 沙洲
- Tombolo 連島沙洲

ALL of these are formed by waves

## THE WORK OF WAVES & TIDES

- **Waves** – driven by wind
  - Transfer of energy from the atmosphere to the water
- Due to friction between moving air & water surface
- Direct wind pressure on the waves
- Energy is used in overturning mineral particles and water as waves break at the shore
  - Erodes shoreline materials, moving the shoreline landward
  - Move sediment along the shoreline
  - Deposit sediment forming beaches and landforms such as barrier islands




## WAVES

- Wave height is determined by wind speed, wind duration, and **fetch** (吹程) length
  - The distance the wind blows over the water

**Table 16.1 Wind speed and wave characteristics**

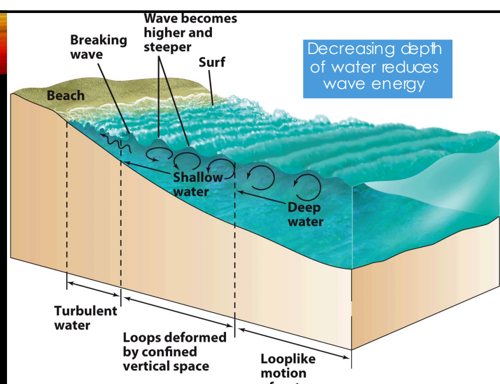
| Sustained wind speed, knots (m/s, mi/hr) | Average wave height, m (ft) | Height of largest waves, m (ft) | Fetch length, km (mi) | Duration, hrs |
|---|---|---|---|---|
| 10 (5, 12) | 0.3 (0.9) | 0.5 (1.8) | 18 (10) | 2.4 |
| 15 (8, 17) | 0.8 (2.5) | 1.5 (5) | 63 (34) | 6 |
| 20 (10, 23) | 1.5 (5) | 3.0 (10) | 140 (75) | 10 |
| 25 (13, 29) | 2.7 (9) | 5.5 (18) | 300 (160) | 16 |
| 30 (15, 35) | 4.3 (14) | 8.5 (28) | 520 (280) | 23 |
| 40 (21, 46) | 8.5 (28) | 17 (57) | 1300 (710) | 42 |
| 50 (26, 58) | 15 (48) | 30 (99) | 2600 (1420) | 69 |

For fully developed waves given a sustained wind speed. Wind speed is shown in knots—nautical miles per hour, where a nautical mile is one minute of longitude at the Equator. Fetch and duration are values required for full development.



Table 16.1

## JAWS, PE'AHI, HAWAII

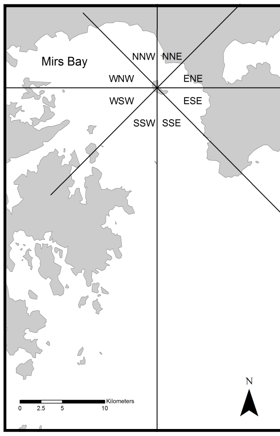

Decreasing depth of water reduces wave energy



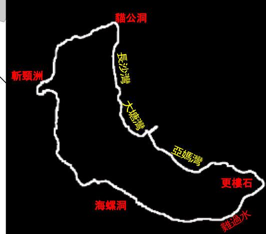
Figure 16.8 part 2

## LOOK AT PHOTO TPC

Observe the long fetch length to the direction where the stacks are located.




## Tung Ping Chau



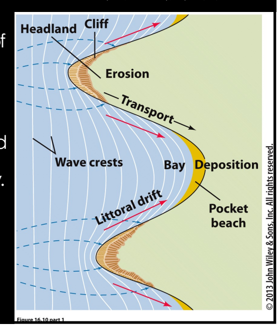

## LOOK AT PHOTO LKW

Observe the coastline along the headlands 岬

What kind of landforms can you find?


## WAVE REFRACTION 波浪折射

- When a wave approaches a coastline of cliffs, its energy is concentrated at the headlands (岬)
- Sediment is eroded from cliffs on the headland and carried by littoral drift along the sides of the bay. The sand is deposited at the head of the bay, forming a pocket beach




## CONSTRUCTIVE VS. DESTRUCTIVE WAVES

Destructive Waves causing erosion

Constructive Waves lead to deposition

## CONSTRUCTIVE WAVES VS. DESTRUCTIVE WAVES CONT.

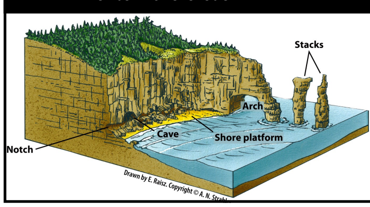
| | *Constructive Wave* | *Destructive Wave* |
|---|---|---|
| *Formation* | Calm weather conditions when wind is weak | Strong winds or storms |
| *Energy* | Low | High |
| *Wave Form* | Low height/Long wavelength | High height/Short wavelength |
| *Wave Frequency* | Low (6-8 per min) | High (10-14 per min) |
| *Shore Gradient* | Gentle | Steep |
| *Strength of swash and backwash* | Strong swash, weak backwash | Weak swash, strong backwash |
| *Gain or loss of shore materials* | Gain | Loss |

## EROSIONAL COASTAL LANDFORMS

- Waves erode weak materials to make marine scarps and attack resistant rocks to make **marine cliffs**


## EROSION OF THE CLIFF

- Weathering, wave action, and gravity erode a marine cliff or headland, forming notches, sea caves, shore platforms, arches, and sea stacks
- Deep indentation – **wave-cut notch**, line of most intense wave erosion
- Points of weakness in the bedrock form crevices and **sea caves**
- Resistant rock may be cut through from both sides to form a **sea arch**
- When arch collapses, rock column (**stack**) remains




## LOOK AT PHOTO TPC

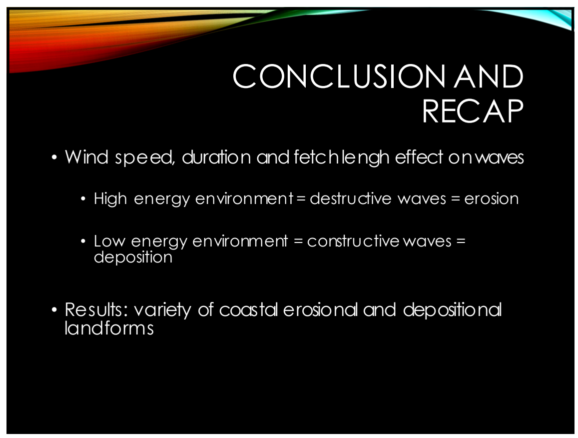
How many coastal landforms can you identified here?

The area shown in the photo is affected by constructive waves or destructive waves?



吊鐘拱門
Tiu Chung Arch


Po Pin Chau破邊洲


CONCLUSION AND RECAP
• Wind speed, duration and fetch lengh effect on waves
• High energy environment = destructive waves = erosion
• Low energy environment = constructive waves = deposition
• Results: variety of coastal erosional and depositional landforms

Coastal Traditional Powerpoint Slides

# COASTAL ENVIRONMENT

Lewis Cheung

## FIELD STUDY DESIGN

- Set your research question and hypothesis
- Identify your field study destinations
- Collect data through various means to answer your research questions and test the hypothesis
- Analysis your collected data and come up with results

## RESEARCH QUESTIONS AND HYPOTHESIS

- **What is the major force to the formation of different coastal environment?**

## COASTAL LANDFORMS

Erosional 侵蝕

- Cliff
- Notch 海蝕凹地
- Sea Cave 海蝕洞
- Geo 海蝕隙
- Sea Arch 海蝕拱
- Sea Stack 海蝕柱
- Wave Cut Platform 海蝕平台

Depositional 沉積

- Beach 海灘
  - Mud flat - Sandy – Boulder
- Sandspit 沙嘴
- Bar 沙洲
- Tombolo 連島沙洲

ALL of these are formed by waves

## COASTAL LANDFORMS

- Virtual field trip
  - Jin Island (JI) 吊鐘洲
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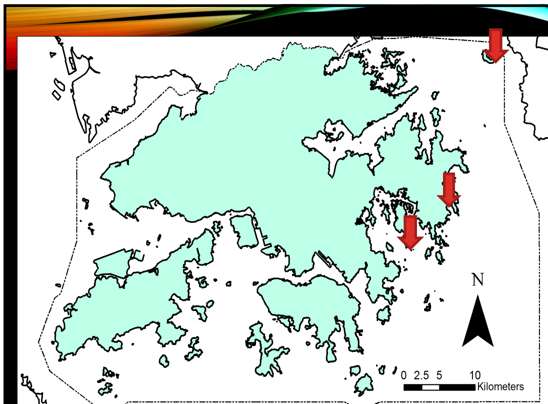
- How were these landforms created?



## JIN ISLAND (JI) 吊鐘洲

## TUNG PING CHAU (TPC) 東坪洲


## LONG KE WAN (LKW) 浪茄灣

## THE WORK OF WAVES & TIDES

- **Waves** – driven by wind
  - Transfer of energy from the atmosphere to the water
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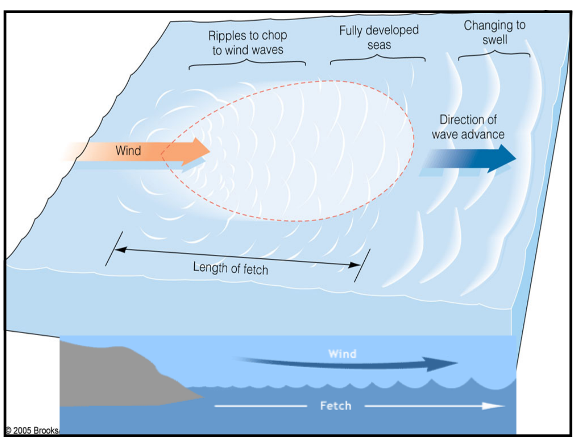


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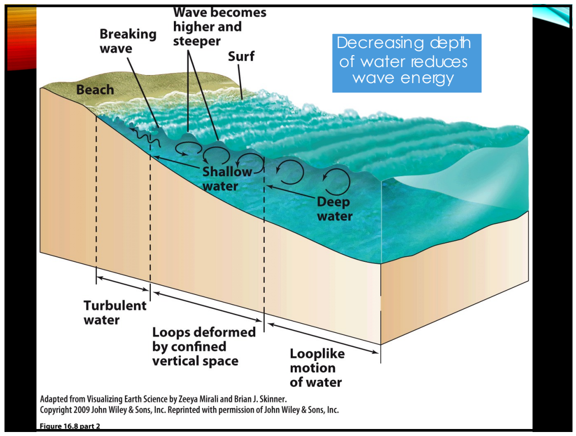
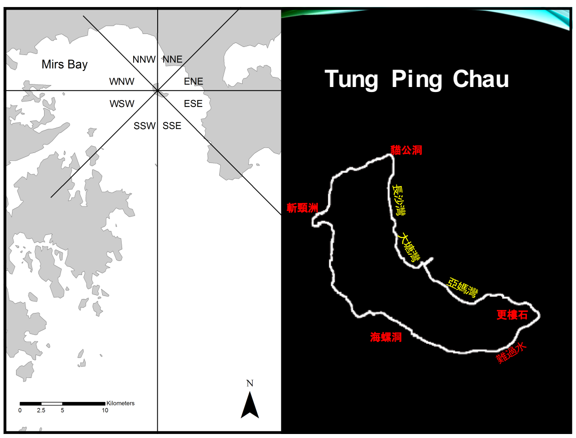
## JAWS, PE'AHI, HAWAII

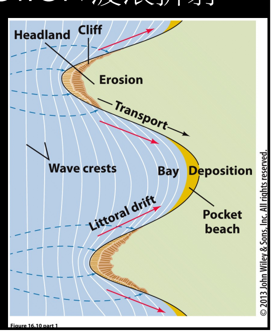





## WAVE REFRACTION 波浪折射

- When a wave approaches a coastline of cliffs, its energy is concentrated at the headlands (岬)
- Sediment is eroded from cliffs on the headland and carried by littoral drift along the sides of the bay. The sand is deposited at the head of the bay, forming a pocket beach




# CONSTRUCTIVE VS. DESTRUCTIVE WAVES

Destructive Waves causing erosion

Constructive Waves lead to deposition

# CONSTRUCTIVE WAVES VS. DESTRUCTIVE WAVES CONT.

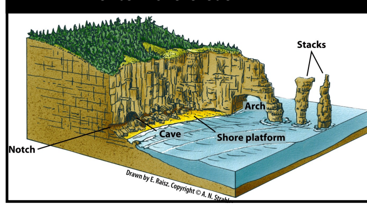
| | *Constructive Wave* | *Destructive Wave* |
|---|---|---|
| ***Formation*** | Calm weather conditions when wind is weak | Strong winds or storms |
| ***Energy*** | Low | High |
| ***Wave Form*** | Low height/Long wavelength | High height/Short wavelength |
| ***Wave Frequency*** | Low (6-8 per min) | High (10-14 per min) |
| ***Shore Gradient*** | Gentle | Steep |
| ***Strength of swash and backwash*** | Strong swash, weak backwash | Weak swash, strong backwash |
| ***Gain or loss of shore materials*** | Gain | Loss |

# EROSIONAL COASTAL LANDFORMS

- Waves erode weak materials to make marine scarps and attack resistant rocks to make **marine cliffs**


# EROSION OF THE CLIFF

- Weathering, wave action, and gravity erode a marine cliff or headland, forming notches, sea caves, shore platforms, arches, and sea stacks
- Deep indentation – **wave-cut notch**, line of most intense wave erosion
- Points of weakness in the bedrock form crevices and **sea caves**
- Resistant rock may be cut through from both sides to form a **sea arch**
- When arch collapses, rock column (**stack**) remains








## CONCLUSION AND RECAP

- Wind speed, duration and fetch lengh effect on waves
  - High energy environment = destructive waves = erosion
  - Low energy environment = constructive waves = deposition
- Results: variety of coastal erosional and depositional landforms

# Appendix G: Teacher’s Manual

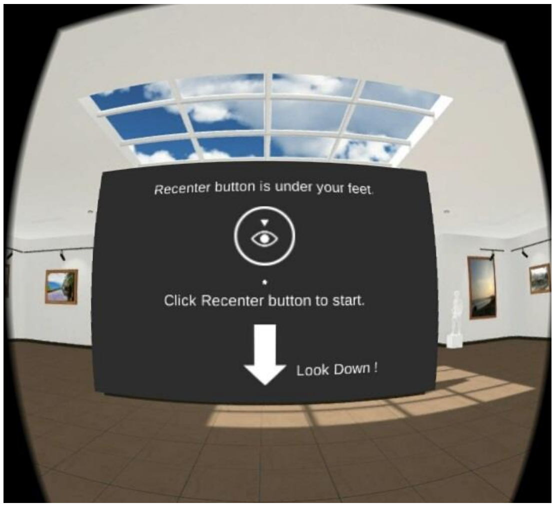
The VR software is called VU gallery.

Setting up the phone (before class):

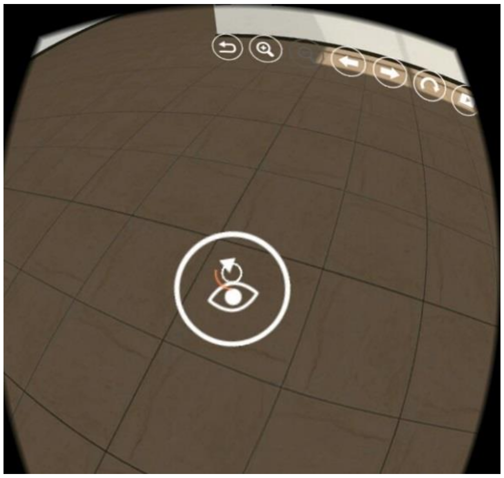
1. Load the images for the lesson onto the phone.
2. Configure the phone so that the screen does not turn off automatically (time out).

Using the VU Gallery app:

1. Open the VU Gallery app.
2. Close the advertisement for VU Pro.
3. Place the phone in the Google Cardboard headset on its side with the screen facing the lenses.
4. Put on the headset; the headset will display a virtual museum gallery, as shown in the figure below.



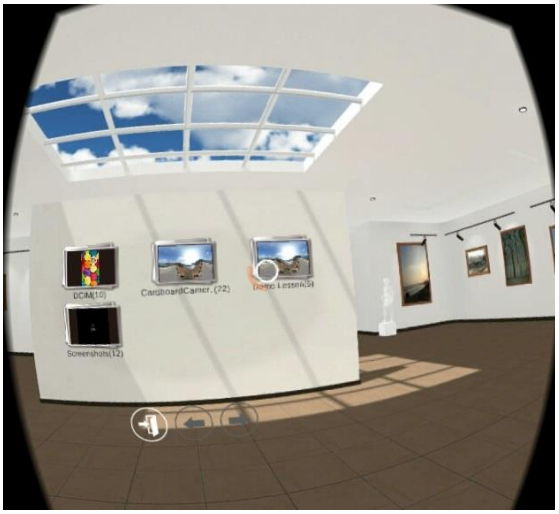

5. Look down at the recenter button on the “floor” of the museum to set the proper orientation of the headset.

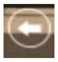
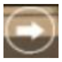


6. Look at the reset button until the circle fills completely.
7. Look up at the gallery again and start viewing photos.

Viewing photos:

1. Look at the folder to be opened.



2. Continue looking until the circle fills completely.
3. Look at the left arrow  or right arrow  on the bar below the pictures until the desired photo is on the screen.
4. Look at the desired photo until the circle fills completely and the photo is large in the center of the screen.

5. Look at the 360 button on the right end of the menu until the picture opens in 360 view mode.

Changing to a different photo:

1. Look downward until a menu appears.


2. Select the return arrow  on the left side of the menu.
3. Select the return arrow  again.
4. Follow steps 3-5 of Viewing photos to select a new photo to view.

Resetting the centering:

1. Select the return arrow  until viewing the gallery screen.
2. Look down at the recentering button on the floor.
3. Look at the reset button until the circle fills completely.

Continue viewing photos.

# Appendix H: Teacher-in-Training Workshop Survey

| | |
|---|---|
| 1. Gender (Circle one) | M / F |
| 2. Age | _____ |
| 3. Are you a geography student? (Circle one) | YES / NO |
| 4. Have you experienced VR (Virtual Reality) before? (Circle one) | YES / NO |
| 5. Do you get motion sickness? (Circle one) | YES / NO |
| 6. Do you wear glasses? (Circle one) | YES / NO |
| 7. I enjoyed the experience. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 8. I felt immersed in the environment. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 9. I found the software easy to use. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 10. I found the hardware easy to use. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 11. The quality of the images are good. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 12. I enjoyed the photographs taken from a high vantage point. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 13. VR made me feel sick or disoriented. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |
| 14. I think VR is a useful tool for teaching geography. | Strongly Disagree Strongly Agree<br>1---------2---------3---------4---------5 |

| | |
|---|---|
| 15. I think the lesson material was well suited for VR. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 16. I think VR could be used as a substitute for a field trip. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 17. I think VR technology needs more improvement before it can be used in general education. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 18. I think students could operate the device with ease. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 19. I think VR devices are too expensive. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 20. It takes too much time to prepare a VR lesson. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 21. I do not have time to collect VR content. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |
| 22. I do not think schools are able to provide technical support for VR technology. | Strongly Disagree 1---------2---------3---------4---------5 Strongly Agree |

23. Please describe any problems you had operating the device (Both hardware and/or software).

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
____________________________________________________________

24. Which image do you think worked the best for teaching geography and why? Image #: _____

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

25. Additional comments

# Appendix I: Lesson Observation Sheet

## VR Section 1 (__-__ Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 2 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

VR Questions:

Additional Comments:

# Lecture Section 1 (__-__ Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

Additional Comments:

# VR Section 2 (__-__ Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 2 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

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VR Questions:

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Additional Comments:

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# Lecture Section 2 (__-__ Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

Additional Comments:

# VR Section 3 (__-__ Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

VR Questions:

Additional Comments:

# Lecture Section 3 (__-__ Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ________________________________

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Additional Comments: ______________________________

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# Appendix J: Observations

## Intro VR Section (~10 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | | X | | X | | | |
| | 2 | x | | X | | X | | | |
| | 3 | x | | x | | X | | | |
| 2 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:
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VR Questions:
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Additional Comments:
____technology was really difficult to figure out/people are snapchatting the VR________

# Lecture Section 1 (~20 Minutes)

| Minut e | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | X | | x | | | |
| 1 | 2 | | | X | | | | | |
| | 3 | | | | | | | | |
| | 1 | | | X | | | | | |
| 3 | 2 | | | X | | x | | | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | X | |
| 5 | 2 | | | | | | | X | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | X | |
| 7 | 2 | | | | | | | X | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | X | |
| 9 | 2 | | | | | X | | X | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | | |
| 11 | 2 | | | | | | | | |
| | 3 | | | | | X | | X | |

**Content Questions:**

**Additional Comments:**

# VR Section 1 (~3 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | | | X | | x | |
| | 2 | X | | | | X | | | |
| | 3 | X | | | | X | | | |
| 2 | 1 | X | | | | X | | | |
| | 2 | X | | | | X | | | |
| | 3 | X | | | | X | | | |
| 3 | 1 | X | | | | X | | | |
| | 2 | X | | | | X | | | |
| | 3 | X | | | | X | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

VR Questions:

Additional Comments: __students generally very confused about setting up the tech/talking about random stuff

# Lecture Section 2 (~5 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | X | | | | | |
| | 2 | | | X | | | | x | |
| | 3 | | | | X | | | | |
| 3 | 1 | | | | | x | | x | |
| | 2 | | | | | | | X | |
| | 3 | | | | | | | X | |
| 5 | 1 | | | | | | | x | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | X | |
| | 2 | | | | | | | X | |
| | 3 | | | | | | | X | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

**Content Questions:**

**Additional Comments:**

# VR Section 2 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | | | | | | |
| | 2 | X | | | | | | X | |
| | 3 | X | | | | | | | |
| 2 | 1 | X | | | | X | | | |
| | 2 | X | | | | X | | | |
| | 3 | X | | | | X | | | |
| 3 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 4 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 5 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 6 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 7 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:
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VR Questions:
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Additional Comments:
_snapchatting VR__________

# Lecture Section 3 (~15 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | M 1 | | | | X | | | X | |
| | F 2 | | | | | | | X | |
| | M 3 | | | | X | | | X | |
| 3 | 1 | | | | | | | X | |
| | 2 | | | | | | | X | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | X | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | X | |
| 7 | 1 | | | | X | | | X | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | X | |
| 9 | 1 | | | | X | | | X | |
| | 2 | | | | | x | | X | |
| | 3 | | | | | | | X | |
| 11 | 1 | | | | | | | X | |
| | 2 | | | | | | | X | |
| | 3 | | | | | | | X | |

Content Questions: ______________________________

Additional Comments: ___throughout the lecture teacher kept trying to stop students from getting distracted/students used their own phones to pull up different pictures__________________________

# VR Section 3 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | | | | X | | X | |
| | 2 | x | | | | x | | X | |
| | 3 | x | | | | X | | X | |
| 2 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 3 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 4 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 5 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 6 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 7 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 8 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |

Content Questions:
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Additional Comments: ____feel dizzy looking at VR/much better without the headset/at this point students have completely lost interest and have begun talking a lot/one student has completely disassembled and put away the headset

## Lecture Section 1 (~20 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | x | | | | | |
| | 2 | x | | x | | | | | |
| | 3 | x | | x | | | | | |
| 3 | 1 | | | x | | | | | |
| | 2 | | | x | | | | | |
| | 3 | | | x | | | | | |
| 5 | 1 | | | x | | | | | |
| | 2 | | | x | | | | | |
| | 3 | | | x | | | | | |
| 7 | 1 | | | x | | | | | |
| | 2 | | | x | | | | | |
| | 3 | | | x | | | | | |
| 9 | 1 | x | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | x | | | | | | | |
| | 3 | x | | | | | | | |

Content Questions: ______________________________

Additional Comments: One student put VR back in case, two students left at ~13 minutes, 6 surrounding students spent 7-8 minutes doing worksheet early. Students playing with VR gear at 14 minutes, most students paying attention, student trying VR on own at 16 minutes

# VR Section 1 (~3 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | | | | x | ? | ? | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 2 | 1 | | | x | | x | ? | ? | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ________________

VR Questions: ________________

Additional Comments: two students still missing. Students talking to teacher, handing headset to them, I think discussing content, chairs conveniently have wheels to spin around

# Lecture Section 2 (~5 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | x | | | | x | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | | | | | | | x | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ______________________________
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Additional Comments: Students back at 27mins. Most students watching professor

# VR Section 2 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | | | | | | | |
| | 2 | x | | x | | x | ? | | |
| | 3 | x | | | | x | | | |
| 2 | 1 | x | | | | x | | | |
| | 2 | x | | | | x | | | |
| | 3 | | | | | x | | | |
| 3 | 1 | x | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | x | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ______________
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VR Questions:
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Additional Comments: Most students done after 3 minutes_________________________

# Lecture Section 3 (~15 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | x | | | | | x | |
| | 2 | x | x | | | | | x | |
| | 3 | x | x | | | | | x | |
| 3 | 1 | ? | | | | | | x | |
| | 2 | ? | | | | | | x | |
| | 3 | ? | | | | | | x | |
| 5 | 1 | | | | | | | x | |
| | 2 | | | | | x | | x | |
| | 3 | | | | | x | | x | |
| 7 | 1 | | | | | x | | x | |
| | 2 | | | | | x | | x | |
| | 3 | | | | | x | | x | |
| 9 | 1 | | | | | x | | x | |
| | 2 | | | | x | x | | x | |
| | 3 | | | x | | | | | |
| 11 | 1 | ? | x | | | x | | x | |
| | 2 | ? | x | | X | x | | x | |
| | 3 | | x | | | x | | x | |

Content Questions: ________________________________

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Additional Comments: students at table are talking to each other, I think answering questions. Student asking question about Geo?

# VR Section 3 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | x | | | | X | x | | |
| | 2 | | | | | x | ? | | |
| | 3 | | | | x | | ? | | |
| 2 | 1 | x | | | | | | | |
| | 2 | x | | | | | | | |
| | 3 | | | | | | | | |
| 3 | 1 | x | | | | x | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ________________

VR Questions: ________________

Additional Comments: Group of students looking straight up and telling a friend to do the same, group at my table is not paying attention, one student used the VR, other two mostly talked

Ending slide show comments: my table not paying attention, others seem to be. One student working on worksheet. Other students starting to work on worksheet. Students trying to draw wave-cut platforms. Discussing with neighbor about drawing on board?

Conclusion: Test being handed out with worksheet still there. Survey handed out at the same time.

Some students using worksheet for test, some students working together. One student using VR during test.

Students asking others for letter answers

## (John Palumbo) Lecture Section 1 (~20 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | X | | | | | |
| | 2 | | | X | | | | | |
| | 3 | | | x | x | | | | |
| 3 | 1 | | | | x | | | | |
| | 2 | | | | | | | | |
| | 3 | | | X | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | x | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | X | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | X | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ________________________________
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Additional Comments: Some students playing with their own cell phones, some having trouble with headset
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# VR Section 1 (~4 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | | | | | X | |
| | 2 | X | | | | | | X | |
| | 3 | X | | | | | | X | |
| 2 | 1 | | | | | X | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 3 | 1 | | | | | X | | | |
| | 2 | X | | | | X | | | |
| | 3 | X | | | | X | | | |
| 4 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | x | | | | X | | | |
| 5 | 1 | | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions:

VR Questions:

Additional Comments: Lots of trouble with headset. Student 1 looks bored

# Lecture Section 2 (~5 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | |
| | 2 | | | X | | | | | |
| | 3 | | | x | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ________________________________

Additional Comments: Student 1 still looks bored_______

# VR Section 2 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | | | | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 2 | 1 | X | | | | X | | | |
| | 2 | X | | | | x | | | |
| | 3 | X | | | | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | x | | | |
| | 3 | | | | | x | | | |
| 4 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Content Questions: ______________
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VR Questions: ____________________
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Additional Comments: Less problems with headset. Student 1 playing with his own phone

# Lecture Section 3 (~15 Minutes)

| Minute | Student | Asking Questions | Participating in Group Discussion | Filling out / reading worksheet | Playing with headset | Playing with phone / electronics | Checking clock | Not paying attention | Napping |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | X | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | X | | | | |
| 3 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 5 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | X | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | X | | | | |
| 9 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 11 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | X | | | | |

Content Questions: ________________________________

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Additional Comments: Student 1 playing with phone for this whole section.

# VR Section 3 (~5 Minutes)

| Minute | Student | Still using VR | Standing Up | Showing Friends | Checking worksheet | Taking headset off | Asking Questions (Content) | Asking Questions (VR) | Looking Up |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | X | | | | | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 2 | 1 | X | | | | | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 3 | 1 | | | | | x | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 4 | 1 | X | | | | | | | |
| | 2 | X | | | | | | | |
| | 3 | X | | | | | | | |
| 5 | 1 | X | | | | X | | | |
| | 2 | | | | | X | | | |
| | 3 | | | | | X | | | |
| 6 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 7 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| 8 | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |

**Content Questions:**

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**VR Questions:**

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**Additional Comments:** Students were able to do phones themselves this time. Student 1 playing with phone.
Students prefer to use phone without headset.
Students finishing worksheet. Test is more difficult because it is in English.

# Appendix K: Pre/Post Test Results and Analysis

## Virtual Reality Results

| Class Number | Pre Test Score (Out of 5) | Post Test Score (Out of 5) | Change in Score | |
|---|---|---|---|---|
| 1 | 2 | 5 | 3 | |
| 2 | 1 | 2 | 1 | |
| 5 | 3 | 5 | 2 | |
| 6 | 0 | 2 | 2 | |
| 8 | 1 | 3 | 2 | |
| 12 | 0 | 2 | 2 | |
| 13 | 2 | 3 | 1 | |
| 15 | 1 | 4 | 3 | |
| 16 | 0 | 4 | 4 | |
| 17 | 1 | 1 | 0 | |
| 18 | 2 | 2 | 0 | |
| 19 | 0 | 1 | 1 | |
| 27 | 1 | 3 | 2 | |
| 29 | 2 | 4 | 2 | |
| 30 | 1 | 2 | 1 | Only Post Test without class number |
| 32 | 1 | 2 | 1 | |
| 33 | 2 | 3 | 1 | |
| 34 | 2 | 2 | 0 | |
| 35 | 1 | 1 | 0 | |
| | | | 1.47 | Average Improvement |
| | | | 1.12 | Standard Deviation |

| | | |
|---|---|---|
| 21 | Not Received | 4 |

t-Test: Paired Two Sample for Means
VR Pretest score vs. Posttest score

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 1.210526316 | 2.684210526 |
| Variance | 0.730994152 | 1.561403509 |
| Observations | 19 | 19 |
| Pearson Correlation | 0.481694885 | |
| Hypothesized Mean Difference | 0 | |
| df | 18 | |
| t Stat | -5.715476066 | |
| P(T<=t) one-tail | 1.01439E-05 | |
| t Critical one-tail | 1.734063607 | |
| P(T<=t) two-tail | 2.02877E-05 | |
| t Critical two-tail | 2.10092204 | |

Control Group
With p5 students

| Student Number | Pre Test Score (Out of 12) | Post Test Score (Out of 12) | Change in Score | |
|---|---|---|---|---|
| 1 | 5 | 7 | 2 | |
| 2 | 4 | 7 | 3 | |
| 3 | 5 | 8 | 3 | |
| 4 | 3 | 4 | 1 | |
| 5 | 2 | 6 | 4 | |
| 6 | 2 | 10 | 8 | |
| 7 | 0 | 10 | 10 | |
| 8 | 3 | 6 | 3 | |
| 9 | 2 | 4 | 2 | |
| 10 | 2 | 4 | 2 | |
| 11 | 3 | 3 | 0 | |
| | | | 3.45 | Average |
| | | | 2.98 | Standard Deviation |

| Student Number | Pre Test Score (Out of 5) | Post Test Score (Out of 5) | Change in Score | |
|---|---|---|---|---|
| 1 | 2 | 5 | 3 | |
| 2 | 2 | 5 | 3 | |
| 3 | 3 | 5 | 2 | |
| 4 | 3 | 2 | -1 | |
| 5 | 2 | 2 | 0 | |
| 6 | 2 | 5 | 3 | |
| 7 | 0 | 5 | 5 | |
| 8 | 3 | 4 | 1 | |
| 9 | 1 | 2 | 1 | |
| 10 | 2 | 3 | 1 | |
| 11 | 2 | 2 | 0 | |
| | | | 1.64 | Average |
| | | | 1.75 | Standard Deviation |

Control Group
With known p5 students removed

| Student Number | Pre Test Score (Out of 12) | Post Test Score (Out of 12) | Change in Score | |
|---|---|---|---|---|
| 1 | 5 | 7 | 2 | |
| 2 | 4 | 7 | 3 | |
| 3 | 5 | 8 | 3 | |
| 4 | 3 | 4 | 1 | |
| 5 | 2 | 6 | 4 | |
| 6 | 2 | 10 | 8 | |
| 7 | 0 | 10 | 10 | |
| 9 | 2 | 4 | 2 | |
| 10 | 2 | 4 | 2 | |
| 11 | 3 | 3 | 0 | |
| | | | 3.50 | Average |
| | | | 3.14 | Standard Deviation |

| Student Number | Pre Test Score (Out of 5) | Post Test Score (Out of 5) | Change in Score | |
|---|---|---|---|---|
| 1 | 2 | 5 | 3 | |
| 2 | 2 | 5 | 3 | |
| 3 | 3 | 5 | 2 | |
| 4 | 3 | 2 | -1 | |
| 5 | 2 | 2 | 0 | |
| 6 | 2 | 5 | 3 | |
| 7 | 0 | 5 | 5 | |
| 9 | 1 | 2 | 1 | |
| 10 | 2 | 3 | 1 | |
| 11 | 2 | 2 | 0 | |
| | | | 1.70 | Average |
| | | | 1.83 | Standard Deviation |

t-Test: Two-Sample Assuming Equal Variances
Traditional Lesson Pretest vs. Posttest scores

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 1.9 | 3.6 |
| Variance | 0.76666667 | 2.266666667 |
| Observations | 10 | 10 |
| Pooled Variance | 1.51666667 | |
| Hypothesized Mean Difference | 0 | |
| df | 18 | |
| t Stat | -3.0866604 | |
| P(T<=t) one-tail | 0.00318111 | |
| t Critical one-tail | 1.73406361 | |
| P(T<=t) two-tail | 0.00636221 | |
| t Critical two-tail | 2.10092204 | |

t-Test: Two-Sample Assuming Unequal Variances
Control Group Improvement vs. VR Improvement

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 1.63636364 | 1.47368421 |
| Variance | 3.05454545 | 1.26315789 |
| Observations | 11 | 19 |
| Hypothesized Mean Difference | 0 | |
| df | 15 | |
| t Stat | 0.27729844 | |
| P(T<=t) one-tail | 0.39266804 | |
| t Critical one-tail | 1.75305036 | |
| P(T<=t) two-tail | 0.78533608 | |
| t Critical two-tail | 2.13144955 | |

# Appendix L: Secondary School Student Survey Responses

| student | Question 1 | Question 2 | Question 3 | Question 4 | Question 5 | Question 6 | Question 7 | Question 8 | Question 9 | Question 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 3 |
| 2 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 5 |
| 5 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 3 | 4 | 5 |
| 6 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 3 | 4 | 5 |
| 8 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 4 | 4 | 4 |
| 12 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 13 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 5 |
| 15 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 |
| 16 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 |
| 17 | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 2 |
| 18 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 5 |
| 19 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 21 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 5 |
| 27 | 5 | 5 | 5 | 5 |  | 5 | 5 | 5 | 5 | 5 |
| 29 | 4 | 5 | 4 | 4 | 5 | 3 | 4 | 5 | 4 | 5 |
| 30 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 32 | 4 | 3 |  | 5 | 4 |  | 3 | 4 | 4 | 5 |
| 33 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 5 |
| 34 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 4 |
| 35 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| AVG | 4.10 | 3.95 | 4.16 | 4.10 | 4.21 | 3.95 | 3.95 | 3.90 | 4.10 | 4.40 |
| STD DEV | 0.64 | 0.83 | 0.69 | 0.72 | 0.79 | 0.71 | 0.76 | 0.72 | 0.72 | 0.82 |

| | *Question 1* | *Question 2* | *Question 3* | *Question 4* | *Question 5* | *Question 6* | *Question 7* | *Question 8* | *Question 9* | *Question 10* |
|---|---|---|---|---|---|---|---|---|---|---|
| Question 1 | 1 | | | | | | | | | |
| Question 2 | 0.706441434 | 1 | | | | | | | | |
| Question 3 | 0.820191673 | 0.494309178 | 1 | | | | | | | |
| Question 4 | 0.549010813 | 0.541479368 | 0.554377837 | 1 | | | | | | |
| Question 5 | 0.657563637 | 0.647034105 | 0.597614305 | 0.479345882 | 1 | | | | | |
| Question 6 | 0.611528097 | 0.386030579 | 0.705023988 | 0.452941176 | 0.478091444 | 1 | | | | |
| Question 7 | 0.76825251 | 0.667613615 | 0.758084005 | 0.492322947 | 0.614377678 | 0.634312968 | 1 | | | |
| Question 8 | 0.594761714 | 0.701260164 | 0.472389105 | 0.428571429 | 0.474850866 | 0.309301308 | 0.473016165 | 1 | | |
| Question 9 | 0.663388066 | 0.630246477 | 0.622171017 | 0.795918367 | 0.479345882 | 0.331795949 | 0.68539077 | 0.530612245 | 1 | |
| Question 10 | 0.720576692 | 0.652438254 | 0.66997375 | 0.732142857 | 0.809197706 | 0.414378897 | 0.625057075 | 0.517857143 | 0.732142857 | 1 |

# Appendix M: Teacher-in-Training Student Survey Responses

| Student | Gender | Age | Geo Major | Used VR | Motion Sick | Glasses |
|---|---|---|---|---|---|---|
| 1 | F | 18 | YES | YES | YES | NO |
| 2 | F | 18 | YES | YES | NO | YES |
| 3 | F | 18 | YES | YES | NO | YES |
| 4 | F | 18 | YES | NO | NO | YES |
| 5 | F | 21 | YES | YES | YES | YES |
| 6 | F | 19 | YES | YES | NO | YES |
| 7 | F | 18 | YES | YES | NO | YES |
| 8 | F | 18 | YES | | NO | YES |
| 9 | F | 18 | NO | YES | NO | YES |
| 10 | F | 18 | YES | YES | NO | YES |
| 11 | F | 20 | YES | NO | NO | NO |
| 12 | M | 20 | YES | YES | NO | NO |
| 13 | F | 18 | YES | YES | NO | NO |
| 14 | M | 19 | YES | YES | NO | NO |
| 15 | M | 21 | YES | YES | YES | YES |
| 16 | F | 18 | YES | NO | NO | NO |
| 17 | F | 19 | YES | YES | NO | YES |
| 18 | M | 18 | YES | YES | NO | YES |
| 19 | M | 19 | YES | YES | NO | YES |
| 20 | F | 21 | YES | YES | NO | NO |
| 21 | M | 18 | YES | YES | NO | YES |
| 22 | F | 18 | NO | YES | NO | NO |
| 23 | M | 18 | YES | YES | YES | YES |
| 24 | F | 19 | NO | YES | NO | NO |
| 25 | F | 18 | NO | NO | NO | NO |
| 26 | F | 19 | NO | NO | NO | YES |

| | | Perceptions | | | | | | Student Perception Average |
|---|---|---|---|---|---|---|---|---|
| Student | Gender | Question 7 | Question 8 | Question 9 | Question 10 | Question 11 | Question 12 | Question 13 |
| 1 | F | 5 | 5 | 5 | 5 | 3 | 4 | 4 | 4 |
| 2 | F | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3.43 |
| 3 | F | 5 | 5 | 4 | 5 | 5 | 5 | 2 | 4.57 |
| 4 | F | 4 | 3 | 3 | 4 | 4 | 4 | 2 | 3.57 |
| 5 | F | 4 | 4 | 3 | 3 | 3 | 3 | 4 | 3 |
| 6 | F | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3.71 |
| 7 | F | 4 | 4 | 3 | 3 | 4 | 4 | 2 | 3.57 |
| 8 | F | 4 | 3 | 4 | 5 | 2 | 4 | 4 | 3.29 |
| 9 | F | 4 | 5 | | 4 | 4 | 4 | 3 | 3.29 |
| 10 | F | 5 | 4 | 4 | 4 | 4 | 4 | 2 | 4 |
| 11 | F | 3 | 4 | 4 | 3 | 3 | 5 | 4 | 3.29 |
| 13 | F | 4 | 5 | 4 | 5 | 4 | 5 | 3 | 4.14 |
| 16 | F | 4 | 3 | 4 | 4 | 3 | 4 | 2 | 3.57 |
| 17 | F | 4 | 5 | 5 | 5 | 4 | 4 | 1 | 4.43 |
| 20 | F | 4 | 4 | 5 | 4 | 5 | 4 | 2 | 4.14 |
| 22 | F | 5 | 5 | 5 | 5 | 5 | 5 | 2 | 4.71 |
| 24 | F | 5 | 5 | 5 | 5 | 4 | 5 | 1 | 4.71 |
| 25 | F | 5 | 4 | 5 | 5 | 4 | 5 | 1 | 4.57 |
| 26 | F | 5 | 5 | 5 | 5 | 5 | 5 | 2 | 4.71 |
| 12 | M | 4 | 3 | 4 | 5 | 4 | 3 | 1 | 3.86 |
| 14 | M | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 3.14 |
| 15 | M | 4 | 3 | 4 | 4 | 2 | 3 | 4 | 3 |
| 18 | M | 4 | 4 | 4 | 4 | 3 | 4 | 1 | 3.86 |
| 19 | M | 5 | 5 | 4 | 4 | 4 | 5 | 2 | 4.29 |
| 21 | M | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4.29 |
| 23 | M | 5 | 5 | 3 | 5 | 5 | 5 | 3 | 4.29 |
| | | | | | | | | | |
| | Average | 4.31 | 4.19 | 4.16 | 4.35 | 3.81 | 4.19 | 2.54 | 3.92 |
| | Female Average | 4.32 | 4.26 | 4.22 | 4.32 | 3.84 | 4.26 | 2.47 | 3.96 |
| | Male Average | 4.29 | 4 | 4 | 4.43 | 3.71 | 4 | 2.71 | 3.82 |

Perceptions T Test | Male vs. Female

t-Test: Two-Sample Assuming Unequal Variances

| | Variable 1 | Variable 2 |
|---|---|---|
| Mean | 3.931579 | 3.8185714 |
| Variance | 0.320736 | 0.3001143 |
| Observations | 19 | 7 |
| Hypothesized Mean Difference | 0 | |
| df | 11 | |
| t Stat | 0.462299 | |
| P(T<=t) one-tail | 0.326438 | |
| t Critical one-tail | 1.795885 | |
| P(T<=t) two-tail | 0.652877 | |
| t Critical two-tail | 2.200985 | |

| e | | Barriers | | | | | | | | | Student Barrier Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Student | Gender | Question 14 | Question 15 | Question 16 | Question 17 | Question 18 | Question 19 | Question 20 | Question 21 | Question 22 | |
| 1 | F | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 | 3.11 |
| 2 | F | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 3 | 2 | 2.89 |
| 3 | F | 5 | 5 | 5 | 2 | 5 | 3 | 2 | 2 | 1 | 3.89 |
| 4 | F | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 2 | 2.78 |
| 5 | F | 4 | 4 | 2 | 4 | 4 | 3 | 3 | 4 | 4 | 2.33 |
| 6 | F | 5 | 5 | 1 | 3 | 4 | 2 | 2 | 2 | 2 | 3.22 |
| 7 | F | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 2 | 3.11 |
| 8 | F | 5 | 5 | 5 | 3 | 5 | 2 | 3 | 2 | 1 | 3.78 |
| 9 | F | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 2.56 |
| 10 | F | 4 | 3 | 2 | 4 | 4 | 2 | 5 | 4 | 2 | 2.33 |
| 11 | F | 3 | 3 | 2 | 5 | 4 | 3 | 2 | 2 | 4 | 2.33 |
| 13 | F | 4 | 5 | 2 | 2 | 4 | 3 | 3 | 3 | 2 | 3 |
| 16 | F | 5 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 2 | 2.89 |
| 17 | F | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 2 | 4 | 2.67 |
| 20 | F | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 2.78 |
| 22 | F | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 3 |
| 24 | F | 5 | 5 | 2 | 4 | 5 | 3 | 3 | 3 | 2 | 3 |
| 25 | F | 4 | 4 | 4 | 5 | 5 | 2 | 1 | 1 | 1 | 3.56 |
| 26 | F | 3 | 3 | 5 | 4 | 5 | 2 | 2 | 1 | 1 | 3.44 |
| 12 | M | 5 | 5 | 1 | 4 | 4 | 3 | 3 | 3 | 3 | 2.67 |
| 14 | M | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 3 | 2.33 |
| 15 | M | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 4 | 2.67 |
| 18 | M | 5 | 4 | 4 | 4 | 5 | 3 | 4 | 3 | 2 | 3 |
| 19 | M | 4 | 4 | 3 | 4 | 4 | 2 | 2 | 2 | 2 | 3.11 |
| 21 | M | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 2.56 |
| 23 | M | 5 | 4 | 3 | 4 | 4 | 3 | 5 | 4 | 5 | 2.22 |
| | | | | | | | | | | | |
| | Average | 4.35 | 4.19 | 3.46 | 3.77 | 4.15 | 3 | 3.04 | 2.81 | 2.5 | 2.89 |
| | Female Average | 4.26 | 4.16 | 3.47 | 3.58 | 4.16 | 2.95 | 2.84 | 2.63 | 2.21 | 2.98 |
| | Male Average | 4.57 | 4.29 | 3.43 | 4.29 | 4.14 | 3.14 | 3.57 | 3.29 | 3.29 | 2.65 |

Barriers T Test | Male vs. Female

t-Test: Two-Sample Assuming Unequal Variances

| | Variable 1 | Variable 2 |
|---|---|---|
| Mean | 2.9826316 | 2.6514286 |
| Variance | 0.2080427 | 0.1050476 |
| Observations | 19 | 7 |
| Hypothesized Mean Difference | 0 | |
| df | 15 | |
| t Stat | 2.0557575 | |
| P(T<=t) one-tail | 0.0288223 | |
| t Critical one-tail | 1.7530504 | |
| P(T<=t) two-tail | 0.0576445 | |
| t Critical two-tail | 2.1314495 | |

| Student | Question 23 | Question 24 | Question 25 |
|---|---|---|---|
| 1 | Not Clear | | |
| 2 | The hardare is quite heavy | The mountain | The photo quality can be improved. |
| 3 | May not know how to use the pictures | Image of coastal landscape | Very useful and good |
| 4 | It seems that too confused to use as the first time to use this device, but it becomes better | Image #1: It help students to identify the specific landscape and let them have a clear memory to recognize it. | |
| 5 | Hardware: not convenient for the students who wearing glass. Software: good. | Image #2: Because I can see the features of the beach by the high vantage point. | |
| 6 | | Volcanos | |
| 7 | No problems | | |
| 8 | The quality of the photos can improve | Clearly shown the features of the landscapes and make students feel immersed into the environment. | A bit dizzy when using the VR devices |
| 9 | | | |
| 10 | No. | Beach that one. It is because teachers may not have sufficient time to take students out for fieldtrip when they are teaching coastal landform. | No |
| 11 | No. | The image taken on the boat, surrounded by igneuos rocks and different erosive features. | Feeling a bit dizzy when using it. |
| 12 | | Beach. It can provide the wide views of the whole beach and it is impossible if not ____ a helicopter | |
| 13 | The pictures make me feel dizzy once I move to other places. | Image #1: It allows students to look at the landform from another perspective with more clearer picture. | |
| 14 | We need to take a lot of time to setup the device. | Image #2: The headland region. We can introduce the headland coastal effect. | The experience is cool. |
| 15 | Software is easy to use while the hardware makes me feel not very well when I look at the device for more than 1 minute. | Image #2: Image 2 is the best for teaching geography because that image is showing the direct relationship of geography as it shows the natural geography | I hope quality of VR image can increase in future development of VR technology |
| 16 | | The sea arch one. I feel really immersed in this image and that I can feel the size of the sea arch. In Hong Kong, students need to go on a boat if they want to see a sea arch. As there are not many sea archs and some students may get sickness when taking a boar, VR will be very suitable to tech such a creature. | |
| 17 | | The first image with the sea arch. It is because students might not able to go there to see the sea arch. | |
| 18 | Hardware: For people who are wearing glasses, it is not convenient for them to use. People need to hold the VR device. Software: Resolution of the images are relatively low. | Beach. It is because it can clearly to show the landforms and easy to identify. Moreover, it can see the characteristics of beach easily. | Change the VR device into head carry. |
| 19 | | The photo taken from the aerial machine. It helps students to understand the landform of coastal area. | Picture can have a higher resolution. Adding description next to the picture? |
| 20 | I think schools are not able to provide technical support for VR technology. | | |
| 21 | If I wear glasses, how can I wear this device comfortable? | The environment | I hope that this device can clear more. |
| 22 | The phone maybe easy to be damaged. And the field is a little blurred | The environment and terrain | It's fine. |

| | | | |
|---|---|---|---|
| 23 | I think this device will made me felt uncomfortable easily. | Some valley and river system to appreciate its spectacular view. | It need to improve to be more clear. |
| 24 | The view is a little bit dim. | The geography environment. | Good. |
| 25 | 1. The image is not so clear. 2. I'm not able to zoom in. (I don't know whether it's my own problem or not.) But generally it's amazing. | | |
| 26 | It's hard to click the cursor at the bottom. Also, we always click the wrong cursor by mistake. And the image is not that clear, and the light is too bright. | Terrain or topography of the ocean and beach. | |

| Correlation Matrix of Questions | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| Question 7 | 1 | | | | | | | | | | | | | | | |
| Question 8 | 0.6 | 1 | | | | | | | | | | | | | | |
| Question 9 | 0.36 | 0.41 | 1 | | | | | | | | | | | | | |
| Question 10 | 0.59 | 0.38 | 0.57 | 1 | | | | | | | | | | | | |
| Question 11 | 0.55 | 0.61 | 0.25 | 0.37 | 1 | | | | | | | | | | | |
| Question 12 | 0.56 | 0.67 | 0.33 | 0.41 | 0.59 | 1 | | | | | | | | | | |
| Question 13 | -0.19 | -0.03 | -0.16 | -0.2 | -0.33 | -0.13 | 1 | | | | | | | | | |
| Question 14 | 0.4 | 0.02 | 0.05 | 0.41 | -0.02 | 0.02 | 0.01 | 1 | | | | | | | | |
| Question 15 | 0.15 | 0.08 | 0.11 | 0.48 | 0 | 0 | 0.13 | 0.67 | 1 | | | | | | | |
| Question 16 | 0.22 | 0.15 | 0.3 | 0.27 | 0.05 | 0.12 | 0.16 | -0.01 | -0.02 | 1 | | | | | | |
| Question 17 | -0.01 | 0.01 | 0.22 | -0.14 | -0.06 | 0.01 | 0.1 | -0.28 | -0.38 | 0.03 | 1 | | | | | |
| Question 18 | 0.4 | 0.34 | 0.33 | 0.44 | 0.13 | 0.46 | -0.12 | 0.15 | 0.23 | 0.22 | 0.15 | 1 | | | | |
| Question 19 | -0.28 | 0 | -0.08 | -0.08 | -0.06 | -0.31 | 0.3 | 0 | 0.18 | 0.28 | 0.07 | -0.28 | 1 | | | |
| Question 20 | -0.02 | -0.06 | -0.13 | 0.1 | -0.04 | -0.23 | 0.09 | 0.22 | -0.08 | -0.05 | 0.06 | -0.15 | 0.3 | 1 | | |
| Question 21 | 0.04 | 0.05 | -0.2 | -0.08 | 0.05 | -0.23 | 0.4 | 0.29 | 0.13 | -0.13 | 0.1 | -0.22 | 0.55 | 0.72 | 1 | |
| Question 22 | -0.29 | 0.02 | -0.21 | -0.24 | -0.02 | -0.22 | 0.38 | -0.03 | -0.14 | -0.23 | 0.4 | -0.41 | 0.37 | 0.47 | 0.56 | 1 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Everyone | | | | | | | | | | | | | | | | | |
| Count: | 26 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 1 | Average Answer | 4.31 | 4.19 | 4.16 | 4.35 | 3.81 | 4.19 | 2.54 | 4.35 | 4.19 | 3.46 | 3.77 | 4.15 | 3.00 | 3.04 | 2.81 | 2.50 |
| | | Standard Deviation | 0.62 | 0.80 | 0.69 | 0.69 | 0.90 | 0.75 | 1.14 | 0.69 | 0.63 | 1.24 | 0.82 | 0.61 | 0.69 | 0.96 | 0.94 | 1.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Female | | | | | | | | | | | | | | | | | |
| Count: | 19 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.73 | Average Answer | 4.32 | 4.26 | 4.22 | 4.32 | 3.84 | 4.26 | 2.47 | 4.26 | 4.16 | 3.47 | 3.58 | 4.16 | 2.95 | 2.84 | 2.63 | 2.21 |
| | | Standard Deviation | 0.58 | 0.73 | 1.20 | 0.75 | 0.83 | 0.65 | 1.02 | 0.65 | 0.69 | 1.26 | 0.84 | 0.60 | 0.71 | 0.90 | 0.90 | 0.98 |
| | Male | | | | | | | | | | | | | | | | | |
| Count: | 7 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.27 | Average Answer | 4.29 | 4.00 | 4.00 | 4.43 | 3.71 | 4.00 | 2.71 | 4.57 | 4.29 | 3.43 | 4.29 | 4.14 | 3.14 | 3.57 | 3.29 | 3.29 |
| | | Standard Deviation | 0.76 | 1.00 | 0.58 | 0.53 | 1.11 | 1.00 | 1.50 | 0.79 | 0.49 | 1.27 | 0.49 | 0.69 | 0.69 | 0.98 | 0.95 | 1.11 |
| Correlation between male and female | | | 0.86 | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | People with VR Experience | | | | | | | | | | | | | | | | | |
| Count: | 20 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.77 | Average Answer | 4.35 | 4.35 | 4.16 | 4.35 | 3.90 | 4.10 | 2.55 | 4.45 | 4.30 | 3.35 | 3.75 | 4.10 | 3.10 | 3.20 | 3.05 | 2.70 |
| | | Standard Deviation | 0.59 | 0.75 | 1.15 | 0.67 | 0.85 | 0.79 | 1.15 | 0.60 | 0.57 | 1.27 | 0.79 | 0.55 | 0.64 | 0.89 | 0.83 | 1.03 |
| | People without VR Experience | | | | | | | | | | | | | | | | | |
| Count: | 5 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.19 | Average Answer | 4.20 | 3.80 | 4.20 | 4.20 | 3.80 | 4.60 | 2.20 | 3.80 | 3.60 | 3.60 | 4.00 | 4.20 | 2.80 | 2.40 | 2.00 | 2.00 |
| | | Standard Deviation | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.55 | 1.10 | 0.84 | 0.55 | 1.14 | 1.00 | 0.84 | 0.84 | 1.14 | 1.00 | 1.22 |
| Correlation between VR and no-VR experienc | | | 0.88 | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | People with Motion Sickness | | | | | | | | | | | | | | | | | |
| Count: | 4 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.15 | Average Answer | 4.50 | 4.25 | 3.75 | 4.25 | 3.25 | 3.75 | 3.75 | 4.75 | 4.25 | 3.50 | 4.00 | 3.75 | 3.25 | 3.50 | 3.50 | 3.75 |
| | | Standard Deviation | 0.58 | 0.96 | 0.96 | 0.96 | 1.26 | 0.96 | 0.50 | 0.50 | 0.50 | 1.29 | 0.00 | 0.50 | 0.50 | 1.00 | 0.58 | 1.26 |
| | People without Motion Sickness | | | | | | | | | | | | | | | | | |
| Count: | 22 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.85 | Average Answer | 4.27 | 4.18 | 4.24 | 4.36 | 3.91 | 4.27 | 2.32 | 4.27 | 4.18 | 3.45 | 3.73 | 4.23 | 2.95 | 2.95 | 2.68 | 2.27 |
| | | Standard Deviation | 0.63 | 0.80 | 1.09 | 0.66 | 0.81 | 0.70 | 1.09 | 0.70 | 0.66 | 1.26 | 0.88 | 0.61 | 0.72 | 0.95 | 0.95 | 0.94 |
| Correlation between motion sickness | | | 0.54 | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | People with glasses | | | | | | | | | | | | | | | | | |
| Count: | 16 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.62 | Average Answer | 4.38 | 4.25 | 3.93 | 4.25 | 3.81 | 4.13 | 2.69 | 4.38 | 4.13 | 3.69 | 3.69 | 4.19 | 2.94 | 3.13 | 2.88 | 2.56 |
| | | Standard Deviation | 0.50 | 0.77 | 1.20 | 0.68 | 0.98 | 0.72 | 1.14 | 0.62 | 0.62 | 1.20 | 0.70 | 0.66 | 0.77 | 1.02 | 1.09 | 1.26 |
| | People without glasses | | | | | | | | | | | | | | | | | |
| Count: | 10 | | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 |
| % of students | 0.38 | Average Answer | 4.20 | 4.10 | 4.50 | 4.50 | 3.80 | 4.30 | 2.30 | 4.30 | 4.30 | 3.10 | 3.90 | 4.10 | 3.10 | 2.90 | 2.70 | 2.40 |
| | | Standard Deviation | 0.79 | 0.88 | 0.53 | 0.71 | 0.79 | 0.82 | 1.16 | 0.82 | 0.67 | 1.29 | 0.99 | 0.57 | 0.57 | 0.88 | 0.67 | 0.84 |
| Correlation between having glasses or not | | | 0.94 | | | | | | | | | | | | | | | |

# Appendix N: Urban Lesson Materials

## Urban Lesson Plan

Objectives
- Identify different types of urban problems
- Explain what factors cause these problems
- Develop an awareness of how students are affected by these problems

| Duration | Teaching Purpose | Teaching Activity | Teaching Process | Resources |
|---|---|---|---|---|
| 8 minutes | Pretest examination | Administer test | 1. Have students to complete the pretest on urban problems to assess existing knowledge base | • Test |
| 3 minutes | Raise students interest in topic | Ask questions | 1. Questions:<br>a. What is your favorite way to get around a city<br>i.Are there ever any problems you encounter with this method?<br>b. What's your favorite part of this city<br>.What type of buildings are found there?<br>c. What would you consider to be problems in the city that affect you? | |
| 3 minutes | Explain how to use VR Technology | | Using teacher's manual, quickly run through how to set-up the headset, view pictures, and navigate through the media. | • Teacher's manual |

| | | | | |
|---|---|---|---|---|
| 5 minutes | | Allow students to familiarize with VR and look at photos | 1. Have students view first photo<br>2. Students fill out the worksheet | • Powerpoint<br>  ○ Guiding questions<br>• Pictures<br>  ○ Picture 1: Urban problems<br>• Worksheet<br>  ○ Guided questions<br>  ○ Notes section |
| 6 minutes | Learn the different types of urban problems | Review photos just viewed and provide context | 1. Review students answers to guiding questions on worksheet<br>2. Explain why each urban problem is a problem (noise/light pollution from mixed land use etc.) | • Powerpoint<br>  ○ Table of problem definitions |
| 18 minutes | Understand the causes of urban problems | Explain the urbanization cycle. | 1. Describe each stage of the urbanization cycle individually and in more depth | • Powerpoint<br>  ○ Urbanization cycle<br>  ○ Urbanization<br>  ○ Suburbanization<br>  ○ Counter-urbanization<br>  ○ Reurbanization |
| 7 minutes | Learn the different strategies for solving urban problems | | 1. Have students think of what steps they think can be taken to mitigate the problems discussed above (2 min)<br>2. Have students look at photo 2 and fill out second half of worksheet (5 min) | • Powerpoint<br>  ○ Guiding questions<br>  ○ Table of proposed solutions<br>• Pictures<br>  ○ Picture 2: Urban solutions |

| | | | | |
|---|---|---|---|---|
| | | | | • Worksheet<br>   ○ Guided questions<br>   ○ Notes section |
| 5 minutes | Make students think about personal impacts of urban problems | Discussion of how problems affect students directly | 1. Guided discussion<br>a. How students are affected by these problems<br>b. How students contribute to the causes of urban problems<br>c. What students can do to help solve problems | |
| 5 minutes | Conclusion and Recap | | 1. Summary of covered topics<br>a. Definitions of problems<br>b. Urbanization cycle | • Powerpoint<br>   ○ Conclusion and recap |
| 8 minutes | Posttest examination | Administer test | 1. Have students put worksheet away so it can't be used as answers on the test<br>2. Have students to complete the posttest on urban problems to assess new understandings | • Test |

Urban Lesson Slides

# Urban VR Powerpoint Slides

## Urban Problems

## Overview

- Urban problems
- Urbanization cycle
- Solutions

## Virtual Reality

1. Follow the setup instructions in the Using the VU Gallery app of your manual
2. Then, follow the instructions in the Viewing Photos section of your manual to view the first image

## What did you see?

- How are people traveling in this picture?
- What is the purpose of each of the buildings in the picture?
- If you lived in one of these apartments, would you be affected by the nearby road?
- Do the buildings look well maintained?

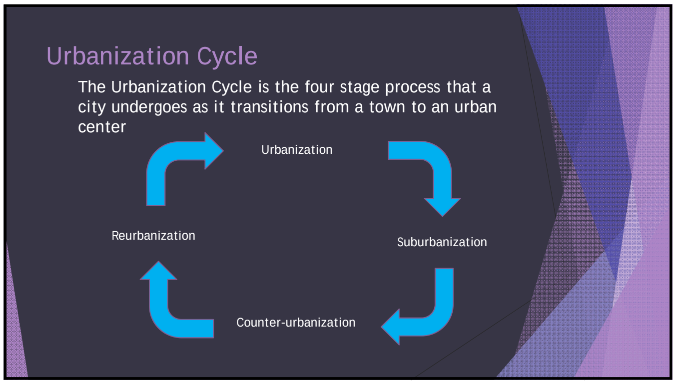
## Urban Problems

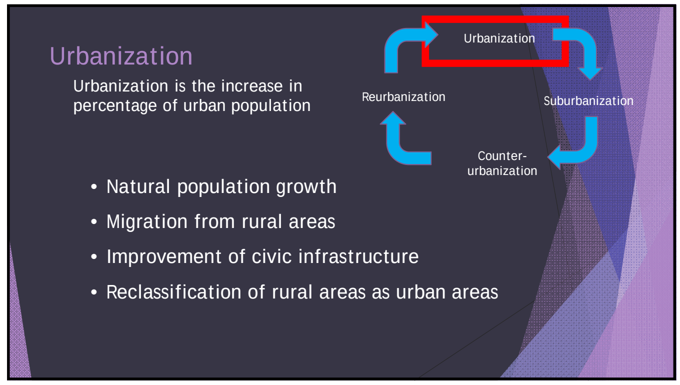
| Problem | Explanation |
|---|---|
| Traffic congestion | Conflicting vehicular and pedestrian traffic cause both to slow down |
| Mixed land use (incorrect zoning) | Different types of buildings (residential, commercial, industrial, retail) all existing on the same block |
| Pollution (air and noise) | Poor air quality or constant unavoidable noise |
| Substandard living conditions | Building owners have no incentives to maintain buildings due to overwhelming demand and poor regulation |

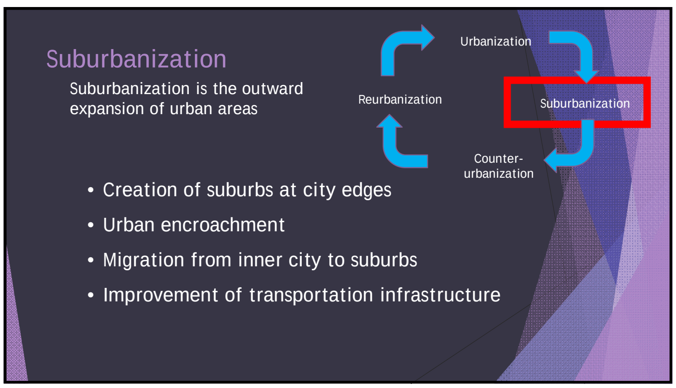
## What causes these problems?

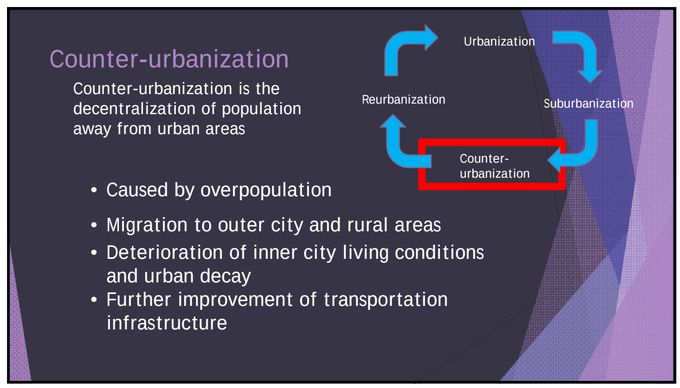
- Overpopulation
- Rapid unstructured city growth
- Infrastructure trying to support changing city needs

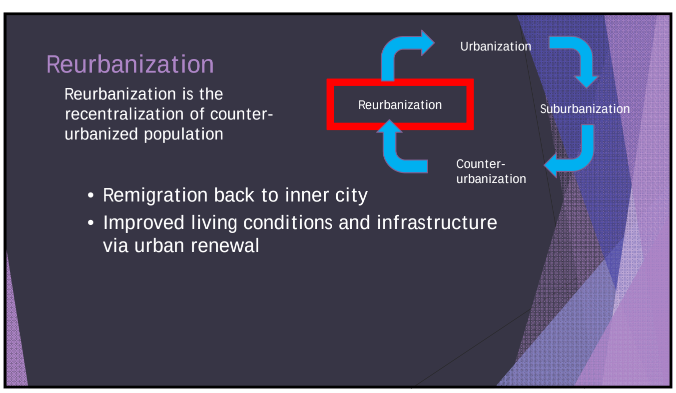
These are all products of the Urbanization Cycle

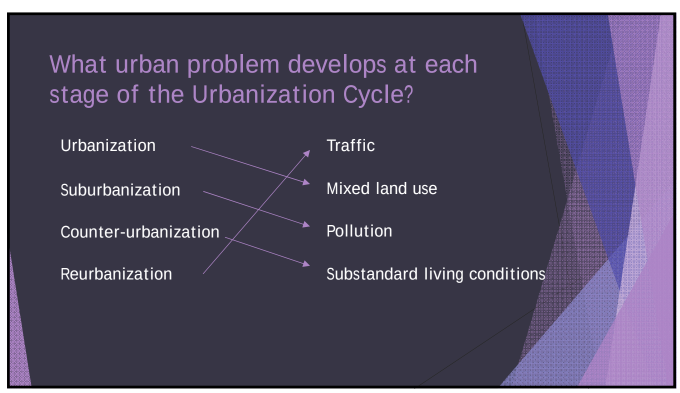

Urbanization Cycle
The Urbanization Cycle is the four stage process that a city undergoes as it transitions from a town to an urban center
Urbanization
Suburbanization
Counter-urbanization
Reurbanization


Urbanization
Urbanization is the increase in percentage of urban population
Urbanization
Suburbanization
Counter-urbanization
Reurbanization
• Natural population growth
• Migration from rural areas
• Improvement of civic infrastructure
• Reclassification of rural areas as urban areas


Suburbanization
Suburbanization is the outward expansion of urban areas
Urbanization
Suburbanization
Counter-urbanization
Reurbanization
• Creation of suburbs at city edges
• Urban encroachment
• Migration from inner city to suburbs
• Improvement of transportation infrastructure


Counter-urbanization
Counter-urbanization is the decentralization of population away from urban areas
Urbanization
Suburbanization
Counter-urbanization
Reurbanization
• Caused by overpopulation
• Migration to outer city and rural areas
• Deterioration of inner city living conditions and urban decay
• Further improvement of transportation infrastructure


Reurbanization
Reurbanization is the recentralization of counter-urbanized population
Urbanization
Suburbanization
Counter-urbanization
Reurbanization
• Remigration back to inner city
• Improved living conditions and infrastructure via urban renewal


What urban problem develops at each stage of the Urbanization Cycle?
Urbanization
Suburbanization
Counter-urbanization
Reurbanization
Traffic
Mixed land use
Pollution
Substandard living conditions

## Virtual Reality

- Follow the instructions in your manual to look at the second photo

## What did you see?

- How are people traveling in this picture?
- What is the purpose of each of the buildings in the picture?
- If you lived in one of these apartments, would you be affected by the nearby road?
- Do the buildings look well maintained?

How do your answers to these questions compare to those from the first photo?

## Solutions

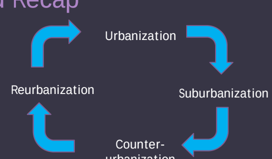
| Problem | Solution |
|---|---|
| Traffic congestion | MTR provides alternatives to vehicular travel. Pedestrian crossings allow pedestrian and vehicular traffic to flow unimpeded by the other |
| Mixed land use (incorrect zoning) | Dedicated residential areas prevent land use mixing and foster the development of dedicated commercial and retail areas |
| Pollution (air and noise) | Increased distance of apartments in high rises from main roads reduces noise pollution |
| Substandard living conditions | Residential complexes allow dedicated staff to maintain large numbers of residences simultaneously |

## Connections

- How are you affected by these urban problems?
- Are you contributing to any of their causes?
- What can you do to help solve them?

## Conclusion and Recap

- Urbanization cycle:




- The urbanization cycle causes many urban problems such as:
  - Traffic, mixed land use, pollution and substandard living conditions
- These problems can be addressed through careful urban planning (infrastructure and zoning)

# Urban Traditional Powerpoint Slides

AHK4

## Urban Problems

## Overview

- Urban problems
- Urbanization cycle
- Solutions

## What did you see?

- How are people traveling in this picture?
- What is the purpose of each of the buildings in the picture?
- If you lived in one of these apartments, would you be affected by the nearby road?
- Do the buildings look well maintained?

## Urban problems

| Problem | Explanation |
|---|---|
| Traffic congestion | Conflicting vehicular and pedestrian traffic cause both to slow down |
| Mixed land use (incorrect zoning) | Different types of buildings (residential, commercial, industrial, retail) all existing on the same block |
| Pollution (air and noise) | Poor air quality or constant unavoidable noise |
| Substandard living conditions | Building owners have no incentives to maintain buildings due to overwhelming demand and poor regulation |

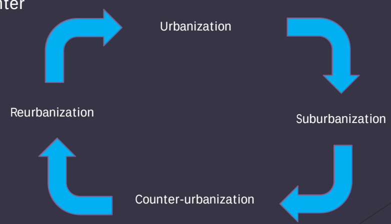
## What causes these problems?

- Overpopulation
- Rapid unstructured city growth
- Infrastructure trying to support changing city needs

These are all products of the Urbanization Cycle

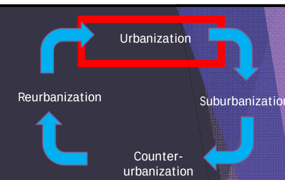
## Urbanization Cycle

The Urbanization Cycle is the four stage process that a city undergoes as it transitions from a town to an urban center




## Urbanization

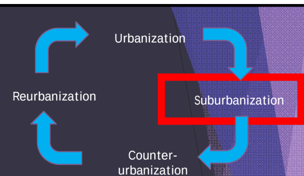
Urbanization is the increase in percentage of urban population




- Natural population growth
- Migration from rural areas
- Improvement of civic infrastructure
- Reclassification of rural areas as urban areas

## Suburbanization

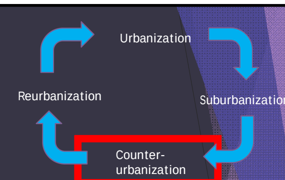
Suburbanization is the outward expansion of urban areas




- Creation of suburbs at city edges
- Urban encroachment
- Migration from inner city to suburbs
- Improvement of transportation infrastructure

## Counter-urbanization

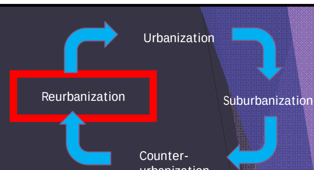
Counter-urbanization is the decentralization of population away from urban areas




- Caused by overpopulation
- Migration to outer city and rural areas
- Deterioration of inner city living conditions and urban decay
- Further improvement of transportation infrastructure

## Reurbanization

Reurbanization is the recentralization of counter-urbanized population




- Remigration back to inner city
- Improved living conditions and infrastructure via urban renewal

## What urban problem develops at each stage of the Urbanization Cycle?

| | |
|---|---|
| Urbanization | Traffic |
| Suburbanization | Mixed land use |
| Counter-urbanization | Pollution |
| Reurbanization | Substandard living conditions |

## What did you see?

- How are people traveling in this picture?
- What is the purpose of each of the buildings in the picture?
- If you lived in one of these apartments, would you be affected by the nearby road?
- Do the buildings look well maintained?

How do your answers to these questions compare to those from the first photo?

## Solutions

| Problem | Solution |
|---|---|
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| Substandard living conditions | Residential complexes allow dedicated staff to maintain large numbers of residences simultaneously |

## Connections

- How are you affected by these urban problems?
- Are you contributing to any of their causes?
- What can you do to help solve them?

## Conclusion and Recap

- Urbanization cycle:

Urbanization → Suburbanization → Counter-urbanization → Reurbanization

- The urbanization cycle causes many urban problems such as:
  - Traffic, mixed land use, pollution and substandard living conditions
- These problems can be addressed through careful urban planning (infrastructure and zoning)

# Worksheet

Picture 1

Notes:____________________________________________________

Questions:

1. How are people traveling in this picture?
2. What is the purpose of each of the buildings in the picture?
3. If you lived in one of these apartments, would you be affected by the nearby road?
4. Do the buildings look well maintained?

Picture 2

Notes:____________________________________________________

Questions:

1. How are people traveling in this picture?
2. What is the purpose of each of the buildings in the picture?
3. If you lived in one of these apartments, would you be affected by the nearby road?
4. Do the buildings look well maintained?

# Pre/Post Test

Class number: __________

Knowledge Assessment for Urban Lesson

There is only one correct answer for each question. Please circle the correct answer [A or B or C or D]

1) Urbanization refers to:
A the increase in the size of an urban population.
B the percentage increase in the urban population.
C the phenomenon that people move from urban areas to rural areas.
D the phenomenon that people move from rural areas to urban areas.

2) Which of the following matching about the processes is correct?
X Rural areas of Hong Kong →Urban areas of Hong Kong ←The mainland of China
Y Suburbs ←Main urban areas
Z Suburbs and other parts of the city→ Redeveloped old urban areas
(→ refers to the movement of population)

| | X | Y | Z |
|---|---|---|---|
| A | Urbanization | Reurbanization | Suburbanization |
| B | Reurbanization | Suburbanization | Urbanization |
| C | Suburbanization | Urbanization | Reurbanization |
| D | Urbanization | Suburbanization | Reurbanization |

3) What are the advantages of urban planning?
1 Alleviating urban problems
2 Using land effectively
3 Managing urban environment in a better way
4 Minimizing land use conflict

A 1 and 3 only
B 2 and 4 only
C 1, 3 and 4 only
D 1, 2, 3 and 4

4) What phenomena does this photograph show?

Credit: Kelvin Ling

1 Urban encroachment
2 Urban renewal
3 Urban decay
4 Land use conflict

A 1 and 4 only
B 2 and 3 only
C 1, 3 and 4 only
D 2, 3 and 4 only

5) In what ways can urban renewal improve the living environment of the inner city?

1 By providing more community facilities
2 By building more industrial buildings
3 By reducing green areas
4 By widening roads

A 1 and 4 only
B 2 and 3 only
C 3 and 4 only
D 1, 2 and 4 only

# Photos for Urban Lessons


**Photo from Mong Kok showing Urban Problems**

**Photo from Shatin – City One showing solutions to urban problems**

**360 degree photo from Mong Kok**

**360 degree photo from Shatin – City One**